DEPARTMENT OF GEOLOGICAL SCIENCES
COLLEGE OF SCIENCES
OLD DOMINION UNIVERSITY
NORFOLK, VA 23508

TECHNICAL REPORT GSTR-88-1

THEORY AND OPERATION OF THE REAL-TIME DATA ACQUISITION SYSTEM FOR THE NASA-LaRC DIFFERENTIAL ABSORPTION LIDAR (DIAL)

By

Carolyn Butler

Submitted by Dr. Randall Spencer, Principal Investigator

Final Report
For the period January 1, 1986 to December 31, 1987

Old Dominion University Research Foundation

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INTRODUCTION

This report documents work performed under Research Grant NCCI-28 toward the improvement of computer hardware and software of the NASA Multipurpose Differential Absorption Lidar (DIAL) system. The NASA DIAL system is undergoing development and experimental deployment at NASA/Langley Research Center (LaRC) for the remote measurement of atmospheric trace gas concentrations from ground and aircraft platforms. A viable DIAL system was developed capable of remotely measuring O_3 and H_2O concentrations from an aircraft platform. Experiments involving the DIAL system were sucessfully performed onboard the NASA/Goddard Flight Center Electra aircraft from 1980-1987 (ref.1) and the NASA/Ames DC-8 in 1987.

The DIAL Data Acquisition System (DAS) has undergone a number of improvements over the past few years. Due to the participation of the DIAL in the Global Troposheric Experiment (GTE), modifications and improvements of the system have been tested and used both in the laboratory environment as well as in the air. The DIAL system, in fact, was the primary system for two experiments in 1987. In the Spring the system was flown on the Electra for 5 weeks over the Amazon for the Amazon Boundary Layer Experiment and in the Fall the system was flown on the DC-8 for stratospheric work during the Ozone Hole experiment.

This report is designed to be used as an operational manual for the DIAL DAS. Many changes were performed on the system during the 1986-1987 time frame. In previous years the system was able to look either above or below the aircraft but not in both directions simultaneously. A change could be made from nadir to zenith operation in a matter of hours on the ground. The major improvement to the system in 1986 was the ability to transmit and receive all wavelengths above as well as below the aircraft. The impact on the data system was to double the amount of data being recorded. In terms of data tapes, this would have meant we would fill up a tape in less than ten minutes at 5 Hz operation. It was decided that for the most part we did not need the 5 Hz horizontal resolution so the digitizers were modified to enable them to perform internal hardware averaging of succesive laser shots. The software was incorporated into the DIAL DAS to program the digitizer averaging memories to select either single shot or 5 shot averages or a combination of both (this will be discussed in more detail in a later section).

The DC-8 which was used for the ozone hole experiment, has only an up-looking window at present. Since the ozone depletion was occurring at altitudes higher than the aircraft could fly we were only interested in zenith transmission. Therefore, the DIAL system was temporarily re-configured to transmit all wavelengths (with some redundancy) in the zenith mode. Since most of the

DIAL work is done in the troposphere, the emphasis in this report will be on our zenith/nadir configuration as performed on the Electra.

The other major improvement to the DIAL system in 1986 was the ability to output real-time color maps of the ozone distribution (as we have been doing with the aerosols for the last few years). Since both LSI 11/23's were already very busy performing the existing data acquisition and real-time analysis, a third processor was added to the system to handle the ozone computations for the color maps. Also, the LSI 11/23 processors were replaced by LSI 11/73 processors with the floating point accelerators to speed up existing computations.

AIRBORNE DIAL SYSTEM

The airborne lidar system uses the DIAL technique for the remote measurement of atmospheric gas profiles. This technique determines the average gas concentration over some selected range interval by differencing the backscatter signals for laser wavelengths tuned on and off the molecular absorption line of the gas under investigation. Two DIAL wavelengths are transmitted with a 300 usec temporal separation. Simultaneously, measurements of aerosol backscatter at multiple wavelengths can be made by transmitting unused (non-doubled) energy from the DIAL system pump lasers. The aerosol measurements are single wavelength returns. Two coaxial receiver systems are used to collect and optically separate the DIAL and aerosol returns. Photomultipler tubes (PMT) and photodiodes detect the backscattered laser returns after optical filtering, and the analog signals from these tubes are digitized, averaged and stored on high-speed magnetic tape.

The lasers can be fired at 1, 5, or 10 Hz. Current operations are to transmit four wavelengths above the aircraft and four wavelengths below the aircraft: an on-line UV and off-line UV for DIAL ozone measurements; an IR aerosol wavelength; and a visible aerosol wavelength. The nadir UV returns are both detected by the same PMT with 300 usec separation and the zenith UV returns are similarly collected by another PMT. The visible wavelengths are collected by two more PMT's and the two IR returns are detected by separate photodiodes. So we have a total of 8 returns detected by 4 PMT's and 2 diodes. The nadir IR return comes from the on-line laser while the zenith IR comes from the off-line laser so there is a 300 usec separation between the two returns. This allows us to sum the two returns with an analog switch (designed by R. J. Allen) prior to being digitized by only one digitizer. The visible returns are obtained in the same manner and digitized by just one digitizer. Present software allows up to four digitizers to be used with no more than 8192 words saved in the computer (10 MHz sampling interval). Of the 8192 words alloted per buffer, at least 40 are reserved for shot header information (shot number, navigation information, energy monitors, etc.) so a safe estimate of the number of words to record per return is obtained by dividing 8100 words per buffer by the total number of returns. However, for the nadir returns we

are usually only interested in the data return to the ground plus
an additional area past the ground return for background
purposes. The zenith returns, on the other hand, are not limited
by ground returns so are of interest for a much greater range.
So we typically record more data words of the zenith returns than
we do of the nadir returns.

DATA ACQUISITION SYSTEM

The DIAL DAS is currently housed in half a double rack (see
figure 1) with digitizers, control electronics and
photomultiplier tube (PMT) power supplies occupying the other
half. This set-up is advisable in that it eliminates the occur-
rence of ground loops between the PMT's and the digitizers.
The DIAL DAS is based upon two Digital Equipment Corporation
(DEC) LSI 11/73 processors and one MDB JFEP-11 front-end proces-
sor. Each LSI has 128K words of 16-bit memory. The overall flow
chart for the DIAL DAS is shown in figure 2. In general, all
data acquisition and storage is performed by the LSI on the left
(LSI #1), while all data display and analysis are performed by
the LSI on the right (LSI #2). LSI #1 does have one data
analysis function. On command, LSI #1 will generate a real-time
color scale representation of range resolved data with averaging
on the ACT II. The JFEP-11 is housed in LSI #2 and has 256K
words of memory of which 128k words can be shared with the host
computer. The JFEP-11 does the DIAL calculation to obtain an
ozone profile, performs a running average on some number of
profiles and returns that average to LSI #2 for color scale
representation on a second ACT II printer.
        LSI #1 acts as the master computer through which the
operator communicates with LSI #2 and the JFEP-11. The operator
communicates with the master's software through a modified Ann
Arbor keyboard (the Ann Arbor CRT has been replaced by one of the
dual Panasonic monitors; the Ann Arbor interface board is
mounted in a separate box). Operator input to LSI #1 is to a
Plessey PM-DLV11J serial line interface with four serial line
ports (the fourth port being the console input). The first
serial port on LSI #1 is used to communicate to the console input
port on an identical PM-DLV11J on LSI #2. The second port is
used to communicate to the JFEP-11 through the SLU (serial line
unit) also housed in LSI #2.
        Data is presented to the operator on either the Panasonic
video monitor through the Matrox QRGB-Graph controller and/or the
system color printers (Act II). Hard copy images of the video
graphics display may be obtained through Polaroid photography or
through a software copy command to the second ACT II (with four
size options). The DSD-480 dual floppy disk units (double sided
and double density capabilities although not presently configured
for either option) are used for storage and retrieval of program
information on both LSI's. The DIAL data is stored real-time
using one of two Cipher F880 magnetic tape units on 731.5 m (2400
ft) reels of 1.27 cm (.5 inch) wide magnetic tape. Two tape
units are required so that continuous data is stored while one
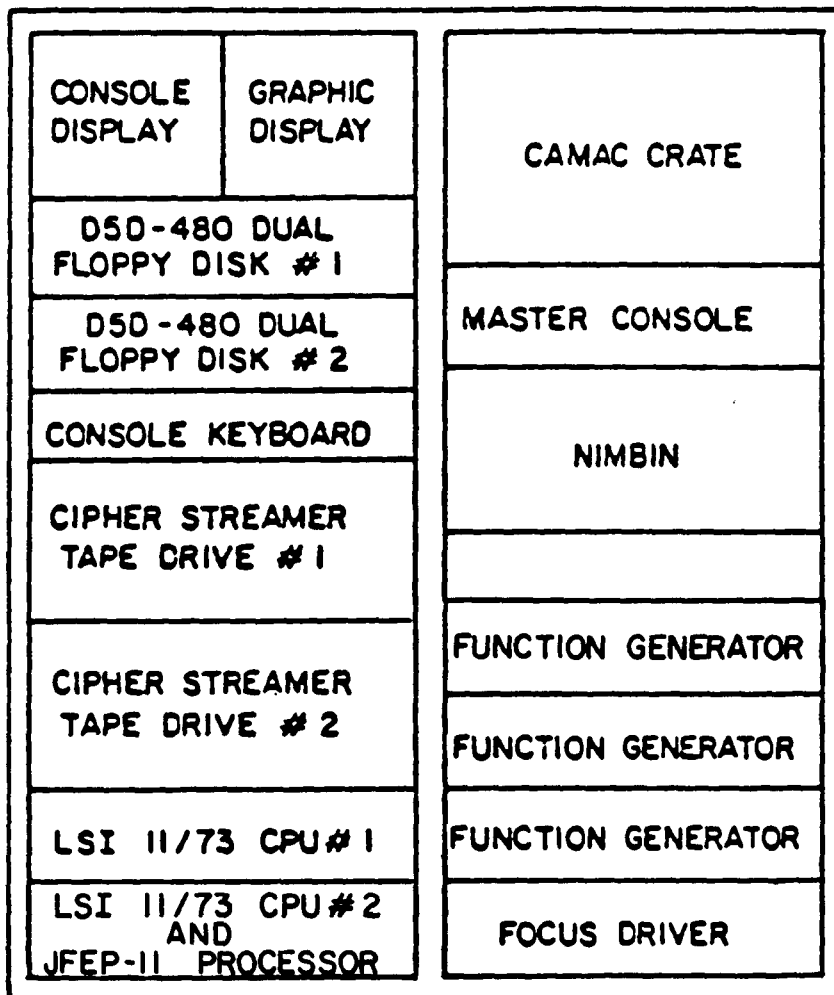
Figure 1. DIAL DAS component configuration in aircraft rack.

JFEP-II SLU

JFEP-II FRONT END PROCESSOR

TCU50 CRYSTAL CLOCK

VIDEO DISPLAY

MATROX QRGB - GRAPH

LSI 11/23 CPU WITH 128 K WORD MOS RAM

DLVIIJ SERIAL LINE INTERFACE (3 SPARE PORTS)

ACT II COLOR PRINTER

LPII LINE PRINTER INTERFACE

DAII BOI INTERPROCESSOR LINK

DSD-480 FLOPPY INTERFACE

DSD-480 DUAL FLOPPY DISK DRIVES

ANN ARBOR CONSOLE AND DISPLAY

DLVIIJ SERIAL LINE INTERFACE (I SPARE PORT)

ACT II COLOR PRINTER

LPII LINE PRINTER INTERFACE

DAII BOI INTERPROCESSOR LINK

DSD-480 FLOPPY INTERFACE

DSD-480 DUAL FLOPPY DISK DRIVES

LSI 11/23 CPU WITH 128 K WORD MOS RAM

CAMAC INTERFACE

DRVII-C PARALLEL I/O @ 40

DRVII-C PARALLEL I/O @ 70

DRVII-C PARALLEL I/O @ 60

DRVII-C PARALLEL I/O @ 50

TCU50-DYR CRYSTAL CLOCK

DQ130 MAGNETIC TAPE INTERFACE

1600 bps PE 100 ips CIPHER 880 TAPE DRIVE

CAMAC CRATE

SPARE

LORAN INTERFACE

ENERGY MONITOR

A/D INPUTS ALT & TEMPS

1600 bps PE 100 ips CIPHER 880 TAPE DRIVE

(DAISY CHAIN)

Figure 2. Computer devices flow chart.

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unit is rewinding. Tape speeds and densities are as follows:
      25 ips @1600 bpi (PE; IBM and ANSI compatible)
      100 ips @1600 bpi (PE; IBM and ANSI compatible)
      50 ips @3200 bpi (PE; not IBM or ANSI compatible)
A Dilog DQ130 provides Cipher interface with the LSI 11/73.

     The acquisition of data is accomplished using four Transiac
Model 2012S waveform digitizers (each with a 4100 averaging
memory).   The Transiacs are manually programmable for digitiza-
tion of analog signals into 12-bit memory of selectable record
lengths (the settings are typically 4096 for DIAL applications)
and selectable record averages.   The internal memories of these
digitizers are made available to the LSI 11/73 through a Kinetics
Systems Direct Memory Access (DMA) interface board.   In addition,
there are four DRV11-C modules in LSI #1 available for parallel
interfacing of TTL digital signals.

SYSTEM CONFIGURATION AND CONNECTION

     Data on system component size, weight, and power consumption
requirements are given in table 1. A drawing of the two
controller box distributions is shown in figure 3.
     One advantage to going with a two computer system is that
one computer can be dedicated to data acquisition while the
second is dedicated to data analysis,   thus allowing for much
more real-time processing of the data.   An additional advantage
is hardware backup. Should one LSI fail, then the other computer

Table 1. DIAL DAS component specifications for size, weight, and
power requirements.

DIAL DAS COMPONENT	Height (in)	Weight (lb)	Power (amp @ 115 Vac)
Magnetic tape drive (2)	8.75	80	1
LSI 11/73 (2)	5.5	35	4
DSD-480 floppy disk (2)	5.5	60	1.5
Panasonic dual monitors	8.75	27	.5
Console keyboard	3.0	7	.5
Camac crate (full)	12.5	105	12
Act II Printer (HxWxD)(2)	8.2 x 22 x 17.9	40	3
Total		569	32

can be used as a totally independent data acquisition system with
limited real-time display capabilities.   In fact, the boards
have been configured inside each LSI (figure 3) so that minimal
changes would be necessary for fall back to a one computer system.

1	M 8192 CPU	DSD-480 FLOPPY INTERFACE
2	DA11 80I INTERPROCESSOR LINK	
3	DQ130 MAG TAPE INTERFACE	
4	CAMAC INTERFACE	
5	DRVII - C @ 70	DRVII- C @ 60
6	DRVII-C @ 50	DRVII-C @ 40
7	LP 11	DLVII-J
8	M 8059 MEMORY (128 K)	TCU 50 - DYR

1	M 8192 CPU	DSD-480 FLOPPY INTERFACE
2	DA11 80I INTERPROCESSOR LINK	
3	MATROX QRGB-GRAPH	
4	JFEP-II FRONT END PROCESSOR	
5	DLVII - J	JFEP-II SLU
6	LP11	TCU-50
7		M 8059 MEMORY (128K)
8		

Figure 3. Internal computer configurations.

Table 2a shows connections from the two LSI's. LSI #2 houses spare boards which need not be connected to anything at present. Table 2b shows various other connections that need be made in order to get the DAS up and running. Table 3 lists the necessary connections to the digitizers. The first item on 2b is a "daisy chain" connection between the two Cipher tape drives. The Cipher 880 manual shows no twist for these cables

Table 2a. DAS component interconnections.

LSI #1 Board	Connector Type	Destination
DSD-480 floppy interface	26p flat cable	DSD-480 #1
DA11BOI interprocessor link	dual 50p flat cables	LSI #2 DA11BOI (F1►F2;F2►F1)
DQ130 magtape interface	dual 50p flat cables	Cipher #1 (J1►F2;J2►F1)
Camac crate interface	50p flat cable	Camac crate
DRV11-C digital interface (@50)	40p flat cable (customized)	A/D interface (N. McRae design)
DRV11-C digital interface (@60)	40p flat cable (customized)	Energy monitor (R. Allen design)
DRV11-C digital interface (@70)	40p flat cable (customized)	Nav interface (N. McRae design)
LP11 line printer controller	36p flat cable	Act II printer
DLV11-J serial line interface	2p EIA (port 4)	Ann Arbor
	2p EIA (port 1)	LSI #2 DLV11 (port 4)
	2p EIA (port 2)	JFEP-11 SLU

LSI #2 Board	Connector Type	Destination
DSD-480 floppy interface	26p flat cable	DSD-480 #2
DA11BOI interprocessor link	dual 50p flat cables	LSI #1 DA11BOI
Matrox QRGB-Graph	75 Ω BNC cable	Panasonic #2
LP11 line printer controller	36p flat cable	Act II printer
DLV11-J serial line	2p EIA (port 4)	LSI #1 DLV11 (port 1)
JFEP-11 SLU	2p EIA	LSI #2 DLV11 (port 2)
JFEP-11	50p flat cable	JFEP-11 SLU

Table 2b.   Other interconnections.

Source	Connector Type	Destination
Cipher #1	50p dual flat cables (half twist)	Cipher #2 (P1►P1;P2►P2)
Ann Arbor interface	26p flat cable	keyboard
	BNC cable	Panasonic #1
	power cable	Power supply

Table 3.   Impedences for digitizer connections.

Transiac	Internal 50 Ω
Trigger	N
Time Base	Y
Input	Y
Amp Input	Y

Available Connections for Digitizers

Lase-Coherent trigger
Master Control trigger
T-0 markers (positive)
T-0 markers (negative)
Diode clippers

but we found a half twist was necessary to make the tape drives function properly. Also, the manual says that only the last unit in the chain should be terminated but we have found that when this is done you cannot turn off one unit (to clear an error) without affecting the other so both our units are terminated. Cipher #2 must have its unit number changed to two to make this configuration work.

The Ann Arbor keyboard/display has functioned reliably and yields good quality characters. The display, however, is large and bulky. A VK-170 (DEC) keyboard kit was tried but the lettering was poor and characters were often thrown out to the screen at random. A new keyboard kit is being investigated but for now the Ann Arbor keyboard and its interface board are being used. The interface board is mounted in a separate box with an external power supply (drawn from LSI #1 chassis).

DIAL DAS PROGRAM THEORY

The NASA multipurpose DIAL DAS has been developed toward optimizing the following:

1.   Speed. The DIAL DAS must be able to digitize and store 8192 words at up to 10 Hz rates as well as retrieve other information such as navigation, laser energies, and meterological data. All this data must be read into computer memory (possibly averaged) and then recorded to magnetic tape prior to the next laser fire. To accomplish this, DMA (direct memory access) devices were chosen.   Timing tests show that it takes about 16 msecs to store 2000 words from the Transiac 2012 digitizer.   To record the data, streamer tape speeds are a neccessity (for 8192 words and 10 Hz).   Since tape units take about 3 minutes to rewind, two streamer tape drives are necessary to avoid interruptions in the data.

2.   Size. Since the LaRC DIAL system is mainly an airplane platform system, size is a major consideration in DAS hardware. The current DIAL DAS is half the size of what it was five years ago with more than three times the computer capability.

3.   Program control. Some experimenters prefer the type of computer system which, once started, runs itself with no operator intervention necessary.   The DIAL DAS is not that kind of system and, in fact, requires this report and some hands-on experience to operate.   The advantage to this type of software is that it allows the experimenter to have maximum control over real-time data acquisition and display.   Near instantaneous modifications can be made to both using the commands detailed in the section "Keyboard Commands".

4.   Data display. There are three purposes to the DIAL DAS data display.   When starting out on a mission a fast refresh plotting capability is needed to align and optimize returns. When a dial or a mirror is turned we need near instantaneous display of that adjustment.   As the mission proceeds we need the capability to monitor our returns but the refresh cycles are not so important.   At this time, however, we need the capability to do some processing of the data to determine ozone and relative aerosol concentrations.   We cannot expect to do all necessary corrections to the data in a real-time situation, so the software has been written to do as much as possible in the one second refresh time allotted.   As an example, ozone concentrations can be calculated but the aerosol correction is not performed. Hardcopy color maps of aerosol concentrations have been extremely useful in DIAL missions in determining aerosol layers and subsequent flight altitudes in and around those layers.   The third purpose to the data display is diagnostics.   There are times when we need to look at the returns in a number of different ways in order to determine why we are getting errors in our concentrations.   If the problem turns out to be something like mis-alignment, the beams can be re-aligned and the data for the mission can be salvaged.

The DIAL DAS has four data display capabilities.   The CRT keyboard monitor can be used to list out raw data, the current

banner record (a record consisting of experimental parameters) or the current plotting options. The second CRT monitor is used for plotting data returns in a number of viewing modes. There are also two color printers, one which is used to generate real-time aerosol concentrations in a 3-D type display and the other is used to generate real-time ozone concentrations in a similar display mode. The second printer can also be used to copy any CRT display. The advantage of having all these display modes is two-fold: (1) maximum control over experiment objectives, and (2) hard-copy data format for post-mission debriefings. The disadvantage is that the DIAL DAS software is long (requires most of the 128K word memory on both computers) and involved (not easily interpreted by other programmers).

Ideally, it would be desirable to see all the data inputs at any processing level on a shot by shot basis but this is usually not possible in a real-time situation. As an example, we used to have two modes of calculating ozone concentrations for CRT display. One mode does a shot-by-shot calculation averaging in each successive concentration. This allows the user to see an updating and converging average and when the specified averaging interval is complete error bars are also shown. To perform the ratios and logarithms each time requires considerable CPU time (about .8 seconds on the LSI 11/73). The other mode averages all the on-line returns and all the off-line returns and does only one DIAL calculation at the end of the specified averaging interval. In this mode, the screen remains empty during the averaging process and no error bars can be calculated, however, the computation is done in about half the time. In real-time situations there is a trade-off between time required to generate a display versus being able to view the data in the most informative way. With hardware averaging of DIAL returns, we are able to achieve concentration averages using the first method at rates equivalent to that of the second method. The second method is no longer available as an option.

The DIAL DAS display modes will be covered in more detail in the section entitled "Real-Time Data Display" and refresh times are cited for each example shown.

PERIPHERAL PROGRAMMING INFORMATION

Table 4 is a summary of the base registers and trap vectors for all the peripheral devices associated with the two LSI computers. The magtape interface is the only device at BR7 -- the highest priority interrupt. The components marked with an asterisk are spare boards with switch registers set as shown.

Table 4. Base addresses for registers used by peripheral devices.

Device	Base Address	Trap Vector
LSI #1		
Floppy Disk	777170	264
Interprocessor Link	772410	124
Mag-tape Interface	772520	224
Camac Interface	777550	400
*DRV11-C @40	767740	
DRV11-C @50	767750	
DRV11-C @60	767760	
DRV11-C @70	767770	300
Line Printer Controller	777514	200
Serial Link (Console)	777560	60
Serial Link (to LSI #2)	776500	320
Serial Link (to JFEP-11)	776510	330
TCU 50-DYR	760770	
LSI #2		
Floppy Disk	777170	264
Interprocessor Link	772410	124
Matrox	764400	
Line Printer Controller	777514	200
Serial Link	777560	60
*TCU 50	760770	
LSI 11/73 Memory Management Registers		
Page Descriptor	772300	
Page Address	772340	
Memory Management 0	777572	
Memory Management 3	772516	

On the following pages each of these peripheral devices will be discussed in a little more detail. The intention here is to provide only enough information to determine if a particular device is functioning properly and for more involved programming requirements references are given for each item.

DSD 480 Floppy Disk System

The DSD 480 is a double sided, double density flexible disk system which is RX02 compatible with RT-11 V3B. However, since the existing DIAL computer system is using RT11 V3 internal

switches were set to make it RX01 compatible (single sided, single density). The floppy disk registers are outlined below.

RXICS   @ 777170   command and status register
RXIDB   @ 777172   data buffer register

RXICS
@ 777170

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ERROR	INIT	XBA17	XBA16	RX02		SIDE SEL	DEN	TRAN REQ	IE	DONE	UNIT SEL	FNC3	FNC2	FNC1	GO
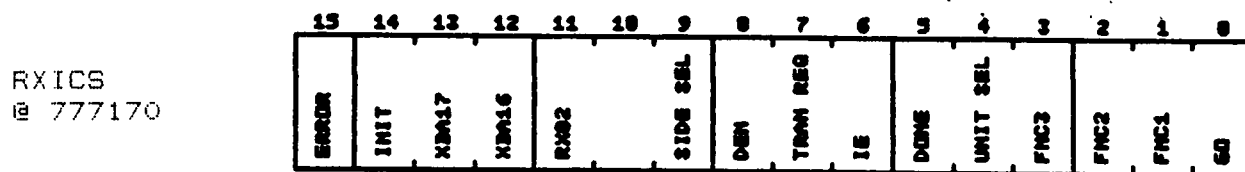
ERROR   Error detected.
INIT   Initialize the DSD 480.
XBA17,XBA16   Extended address bits.
RX02   RX02 system identification bit.
SIDE SEL   Side select: =1 for side 0; =0 for side 1.
DEN   Density of the function encoded in FCN1-FCN3.
TRAN REQ   Transfer request flag.
IE   Allows DONE to interrupt.
DONE   Operation completed.
UNIT SEL   Drive unit select.
FCN3-FCN1   Function select: 000   fill buffer
                                    001   empty buffer
                                    010   write sector
                                    011   read sector
                                    100   set media density
                                    101   read status
                                    110   write deleted data sector
                                    111   read error code
GO   Execute the function.

RXIES
@ 777172

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
				NXM	WC OVFL	SIDE SEL	UNIT SEL	DRV RDY	DEL DATA	DRV DEN	DEN ERR	PWR LO	INIT DN	SD 1 RDY	CRC
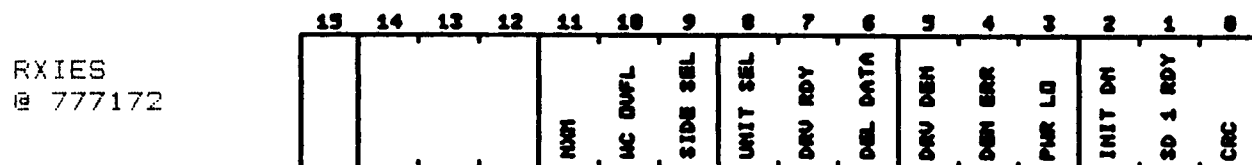
NXM   Non-existent memory error.
WC OVL   Word count overflow.
SIDE SEL   Indicates side selected during last operation.
UNIT SEL   Indicates unit selected during last operation.
DRV RDY   Drive ready -- disk installed and ready to go.
DEL DATA   Deleted data -- indicates deleted data address
                 mark was found on last operation.
DRV DEN   Density of diskette.
DEN ERR   Diskette density did not match DEN.
PWR LO   Power failure in the controller/drive subsystem.
INIT DN   Initialize done.

SD 1 RDY   Set for double sided diskette when ready.
CRC   Cyclic redundancy error.

Interprocessor Link (DA11BOI)

The Interprocessor Link provides a means of transferring
data through DMA between two LSI 11/73 processors. This is the
device used by the DIAL DAS software to transfer a data record
from LSI #1 to LSI #2 to be processed and plotted.

WCNT   @ 772410   word count
ADDR   @ 772412   bus address
STATUS   @ 772414   control/status
DATA   @ 772416   data buffer

STATUS
@ 772414

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ERROR	NEX	ATTN	MAINT	IN IR	IN DIR	IN MODE	CYCLE	READY	IE	XBA17	XBA16	OUT IR	OUT DIR	OUT MODE	GO

ERROR   Set by NEX, ATTN from the other computer or by
               bus address overflow.
NEX   Non-existent memory.
ATTN   Reads ATTN from the other computer.
MAINT   Maintenance.
IN IR   Input interrupt request. Reads status of the OUT IR
               from the other computer.
IN DIR   Input direction. Reads status of OUT DIR from the
               other computer.
IN MODE   Input mode. Reads status of OUT MODE from other
               computer.
CYCLE   Initiates a DMA transfer when the generating DA11BOI
               is both the requested computer and the transmitter.
               When CYCLE and GO are both set, an immediate bus
               cycle is executed.
READY   Must be cleared before a block transfer can be done.
IE   Allows READY, IN IR or ERROR to cause interrupt.
XBA17,XBA16   Extended memory bits.
OUT IR   Causes IN IR and READY in the other computer.
OUT DIR   During block transfer: =0 for transmitter; = 1 for
               receiver. Must be opposite of IN DIR.
OUT MODE   Output mode: =0 for DMA; =1 for program mode.
GO   Executes.

Cipher F880 Interface (Dilog DQ130)

Two Cipher F880 tape drives are available for storage of
data. This allows for continuous data acquisition when one drive

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is rewinding. The two units are cabled together by a "daisy chain" configuration and interfaced to the LSI 11/73 through a

Dilog DQ130 tape coupler. Tape density is determined by a button on each Cipher unit and tape speed is software selectable. The fast speed (100 ips) or streamer mode requires a longer repositioning time if the tape motion stops during read or write operations. The DIAL DAS software must stack data records in extended memory during repositioning times to take advantage of the streamer mode. Tests showed that for 4096 word buffers and 10 Hz DIAL data, 11 or 12 records would get stacked during repositioning. The interface registers are outlined below.

```
MTS      @ 772520      status
MTC      @ 772522      command
MTBRC    @ 772524·     byte/record counter
MTCMA    @ 772526      current memory address
MTD      @ 772530      data buffer
MTRD     @ 772532      tape read lines
```

MTS
@ 772520

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ILL COM	EOF		PAR ERR	BGL	EOT	RLE			NXM	SELR	BOT	7 CH	SDWN	WRL	RWS	TUR

ILL COM   Occurs if (a) a new instruction is issued before last
                 one has finished, (b) no write ring when told to write,
                 (c) a command to unit whose SELR is 0, or (d) SELR
                 becomes 0 during tape operation.
EOF   Set when end of file is detected during tape operation.
PAR ERR   Parity error.
BGL   Bus grant late.
EOT   End of tape marker detected.
RLE   Record length error -- detected during read
                 operations if tape record is too long.
NXM   Non-existent memory.
SELR   Indicates unit addressed is on-line.
BOT   Beginning of tape.
7 CH   Set to indicate 7-channel tape unit.
SDWN   Will accept new command during settle down as long
                 as it is in the same direction.
WRL   Write lock set if no write ring is on tape.
RWS   Rewind status set when rewind command given,
                 cleared at BOT.
TUR   Tape unit ready is cleared by GO and function occurs.

MTC
@772522

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ERROR			PWR CLR	STREAMER		US1	US0	READY		IE	XBA17	XBA16	FCN3	FCN2	FCN1	GO
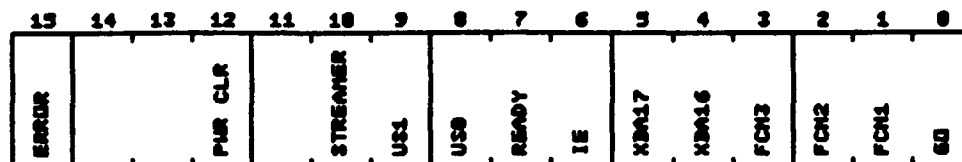
ERROR   Set by bits 7-15 of the status register.
PWR CLR   Clears the control unit and tape units.
STREAMER   Selects streamer mode.
US1,US0   Selects unit number for MTS operation.
READY   Control unit ready.
IE   Interrupt enable.
XBA17,XBA16   Extended memory bits.
FCN3-FCN1   Function bits   (with GO set):
               000   (1)   Off line
               001   (3)   Read
               010   (5)   Write
               011   (7)   Write EOF
               100   (11)   Space Forward
               101   (13)   Space Reverse
               110   (15)   Write with Extended Interrecord Gap
               111   (17)   Rewind
GO   When set, begins operation defined by function.

Camac Interface (Kinetics 2920-Z2B bus adaptor)

The Transiac 2012S digitizers are interfaced to the LSI
11/73 through a Kinetics 3920 Crate Controller and a Kinetics Bus
Adaptor board. The interface is versatile in that any unit in
the Camac crate can be addressed by its slot number. The func-
tion codes will be defined by the type of hardware being used in
that slot. Since this interface is presently being used only for
the Transiac digitizers, only those function codes will be listed
here. The interface has four directly addressable registers plus
an additional 6 registers addressed by offsets.

DLO	@ 777550	data low	(RA2 = 0, RA1 = 0)
LLO		lam low	(RA2 = 0, RA1 = 1)
MAR		memory address	(RA2 = 1, RA1 = 0)
DMACSR		DMA control/status	(RA2 = 1, RA1 = 1)
DHI	@ 777552	data high	(RA2 = 0, RA1 = 0)
LHI		lam high	(RA2 = 0, RA1 = 1)
WCR		word count	(RA2 = 1, RA1 = 0)
EMA		extended memory	(RA2 = 1, RA1 = 1)
NAF	@ 777554	station/function	
CACSR	@ 777556	control/status	

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ASCAN		SLOT4	SLOT3	SLOT2	SLOT1	SLOT0	SA3	SA2	SA1	SA0	FCN4	FCN3	FCN2	FCN1	FCN0

NAF
@ 777554

ASCAN	Enables the crate controller to increment the Camac address on completion of a Dataway Cycle.
SLOT0-SLOT4	Station or slot number of Camac device.
SA0-SA3	Sub-address of Camac device (not used with Transiacs.)
FCN0-FCN4	Function code defined by user device.

Transiac Function Codes

$F(0)*A(0)$	Reads LAM register and record length.
$F(1)*A(0)$	Reads number of sweeps completed.
$F(2)*A(0)$	Reads signal averaged data. Cannot be executed until signal averaging disabled.
$F(8)*A(0)$	Tests LAM and returns $Q = 1$ if ready for readout.
$F(9)*A(0)$	Resets module; clears averaging memory to zero; enables averaging memory.
$F(10)*A(0)$	Resets LAM.
$F(16)*A(0)$	Sets the record length register.
$F(16)*A(1)$	Writes address of the first data word to be read from averaging memory (must be executed twice). A record length of 4K is selected by 100(octal) in DLO register.
$F(17)*A(0)$	Sets the sweep register.
$F(24)*A(0)$	Disables LAM.
$F(24)*A(1)$	Disables averaging and generates a LAM.
$F(26)*A(0)$	Enables LAM to become active on dataway.
$F(26)*A(1)$	Enables averaging.
Z,C	Clear and reset; same as $F(9)*A(0)$.

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ON-LINE	L-SUM	NO-Q	NO-X		N>23	RA2		RA1	DONE	IE	SET N	SET C	SET INH	READ INH		GO

CACSR
@ 777556

ON-LINE (R)	True when 3920 is powered and on-line.
L-SUM (R)	True if any LAM is set in crate (causes interrupt).
NO-Q (R/W)	Updated by 3920 during every Dataway Cycle.
NO-X (R/W)	Updated by 3920 during every Dataway Cycle.
N>23 (R)	During address scan operations, indicates the slot number has been incremented past 23.
RA2,RA1 (R/W)	Used to select registers defined above.
DONE (R)	True when 3920 has completed a progammed control

```
                    operation (i.e. non-DMA).
IE  (R/W)           When set, allows L-SUM to cause interrupt.
SET Z (W)           Dataway initialize.
SET C (W)           Dataway clear (does not affect registers).
SET INH (R/W)       Sets state of Dataway inhibit line.
READ INH (R)        Reflects status of Dataway inhibit line.
GO (W)              Starts 3920 operation defined in NAF and DMACSR.
```

DMACSR
@ 777550
RA2 = 1
RA1 = 1
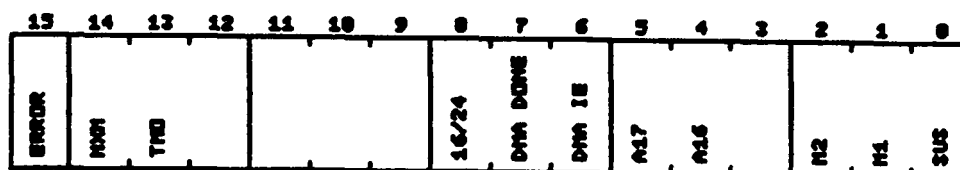

```
ERROR  (R)          Set by NXM, NO-X, N>23, or TMO; cleared by INIT or GO.
NXM  (R)            DMA transfer to non-existent memory attempted.
TMO  (R)            Time-out condition during Q-Repeat DMA mode (mode 3).
16/24  (R/W)        Specifies 16 or 24 bit data transfers (16-bit = 1).
DMA DONE (R)        Set when DMA operation is done.
DMA IE (R/W)        Enables DMA DONE to interrupt.
A17,A16 (R/W)       Extended memory bits used with MAR during DMA.
M2,M1 (R/W)         Specify mode when GO of CACSR is set.
                        mode 0    programmed transfer
                        mode 1    Q-stop/stop on word count
                        mode 2    address scan
                        mode 3    Q-repeat/stop on word count
SUS (R/W)           Set to suspend DMA operation.
```

Parallel Line Interface Module (DRV11-C)

    This module acts as an interface between the LSI 11/73 and a
peripheral device.   The DIAL DAS presently uses one of these
modules to pass data from the LORAN or INS interface to the
computer, one to transfer digital laser energy readings and one
to transfer temperature and altitude information from aircraft
systems.   The X represents 5, 6 or 7 depending on which DRV11-C
is being addressed.

```
DRSR      @ 7677X0          control/status
DRO       @ 7677X2          output buffer
DRI       @ 7677X4          input buffer
```

DRSR
@ 7677X0
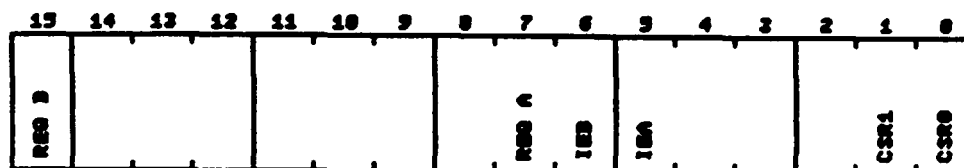
REQ B   Set by user device and causes interrupt if IEB set.

REQ A	Set by user device and causes interrupt if IEA set.
IEB	Interrupt enable for REQ B.
IEA	Interrupt enable for REQ A.
CSR1	User defined function -- if linked to another DRV11-C causes REQ B.
CSR0	User defined function -- if linked to another DRV11-C causes REQ

Analog-to-Digital Converter (ADV11-C)

Sixteen Analog-to Digital Conversion single ended inputs (or eight differential) are available to the DIAL DAS through an ADV11-C board. Unipolar inputs can range from 0V to 10V and bipolar inputs from -10V to +10V and can be stored with programmable gains of 1, 2, 4, or 8 times the input voltage. This board is not being used in the system presently.

| ADST | @ 770400 | control/status |
| ADBF | @ 770402 | data buffer |
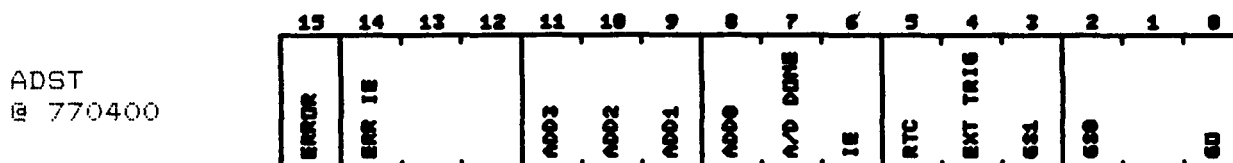
ADST
@ 770400

ERROR	Caused by doing a GO when A/D DONE is set or A/D still in progress.
ERR IE	Allows ERROR to interrupt.
ADD3-ADD0	Channel address.
A/D DONE	Set when A/D done, cleared by reading A/D data buffer.
IE	Interrupt enable.
RTC	Enables real-time-clock input to start A/D conversion.
EXT TRIG	When set allows external trigger to start A/D.
GS1-GS0	Gain select: 00=1, 01=2, 10=4, 11=8.
GO	Starts an A/D conversion -- cleared after starting.

Line Printer Controller (MLSI-LP11)

The LP11 provides the interface between the LSI 11/73 computers and the ACT II printers. Each computer has its own interface board.

| LPS | @ 777514 | status |
| LPB | @ 777516 | data buffer |

LPS
@ 777514
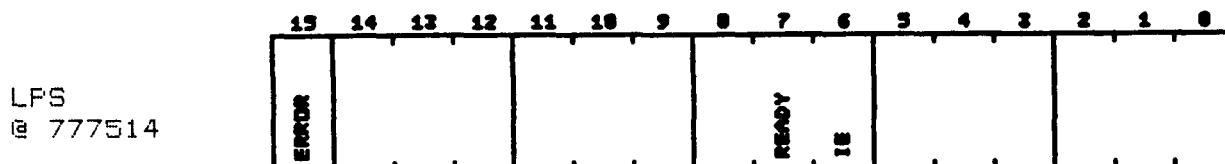
Teletype (Plessey PM-DLV11J Serial Line Interface)

The Plessey PM-DLV11J is a 4-channel asynchronous serial line interface between the LSI 11/73 bus and standard I/O devices. On LSI #1 one port is used to communicate with the teletype, a second port is used to communicate with a second PM-DLV11J interface on LSI #2 and a third port is used to communicate with the JFEP-11 through its SLU board. Baud rates on both boards have been wire-wrapped for 9600 baud.

From LSI #1 port #1 to LSI #2 port #4 (X=0) and from LSI #1 port #2 to JFEP SLU (X=1):

RCSR	@ 7765X0	receiver control/status
RBUF	@ 7765X2	receiver buffer
XCSR	@ 7765X4	transmitter control/status
XBUF	@ 7765X6	transmitter buffer

From LSI #1 port #4 to console device:

RCSR	@ 777560	receiver control/status
RBUF	@ 777562	receiver buffer
XCSR	@ 777564	transmitter control/status
XBUF	@ 777566	Transmitter buffer

RCSR
@ 776500
@ 776510
@ 777560
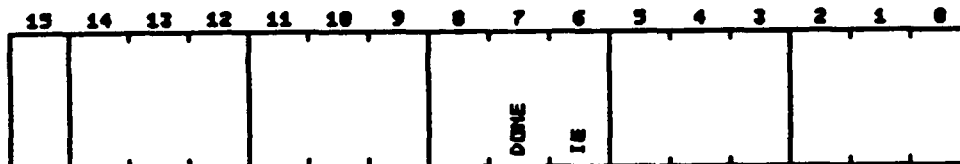
DONE	Set when entire word has been received and is ready for transmission.
IE	When set, allows DONE to cause interrupt.

RBUF
@ 776502
@ 776512
@ 777562
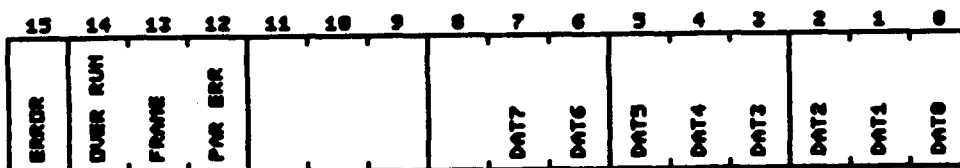
ERROR	Set by bits 14,13, or 12.
OVER RUN	Set when previous character was not completely read prior to receiving a new character.
FRAME	Set when no valid stop bit for character.
PAR ERR	Parity error.
DAT7-DAT0	Received data bits.

```
        15  14  13  12  11  10   9   8   7   6   5   4   3   2   1   0
      ┌───┬───────────┬───────────┬───────┬───────┬───────────┬───────┐
XCSR  │   │           │           │       │       │           │       │
@ 776504                                  READY                       │
@ 776514                                      IE                      │
@ 777564                                                          BREAK
      └───┴───────────┴───────────┴───────┴───────┴───────────┴───────┘
```
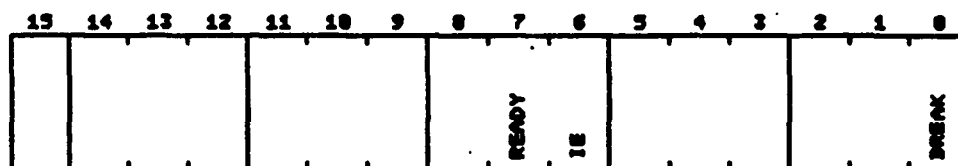
READY   Set when XBUF is ready to receive another character.
IE   Enables READY to cause interrupt.
BREAK   When set, causes a continuous space level to be
            transmitted.

```
        15  14  13  12  11  10   9   8   7   6   5   4   3   2   1   0
      ┌───┬───────────┬───────────┬───────────┬───────────┬───────────┐
XBUF  │   │           │           │           │           │           │
@ 776506                                    DAT7 DAT6 DAT5 DAT4 DAT3 DAT2 DAT1 DAT0
@ 776516
@ 777566
      └───┴───────────┴───────────┴───────────┴───────────┴───────────┘
```
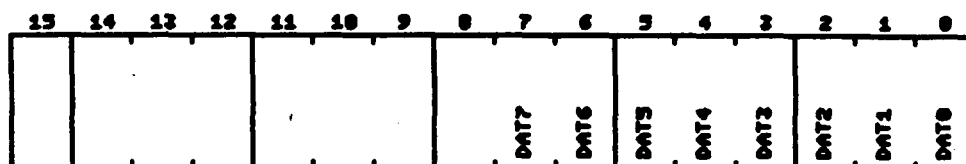
DAT7-DAT0   Transmitter data bits.

Timing Control Unit (TCU-50 and TCU-50 DYR)

These two timing control units are similar in that they are
both crystal clocks that continue to operate even after the
computer has been powered down. The TCU-50 has month, day, hours,
minutes and seconds while the TCU-50 DYR also has year, day of
week as well as .1, .01 and .001 seconds. The two clocks are set
and read differently so both are outlined below. The TCU-50 DYR
is used in LSI #1 while the TCU-50 resides in LSI #2 but is not
currently being used by the DIAL DAS -- it is maintained for
back-up purposes.

TCU-50:

```
            15  14  13  12  11  10   9   8   7   6   5   4   3   2   1   0
          ┌───┬───────────┬───────────┬───────────┬───────────┬───────────┐
MNTH/DAY  │   │           │MONTH MONTH MONTH│MONTH│       │   DAY DAY │DAY DAY DAY│
@ 760770  │   │           │           │           │           │           │
          └───┴───────────┴───────────┴───────────┴───────────┴───────────┘
```

```
            15  14  13  12  11  10   9   8   7   6   5   4   3   2   1   0
          ┌───┬───────────┬───────────┬───────────┬───────────┬───────────┐
HR/MIN    │   │           │HOUR HOUR HOUR│HOUR│       │MINUTE MINUTE MINUTE│MINUTE MINUTE MINUTE│
@ 760772  │   │           │           │           │           │           │
          └───┴───────────┴───────────┴───────────┴───────────┴───────────┘
```

SECND
@ 760774

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
										SECOND	SECOND	SECOND	SECOND	SECOND	SECOND
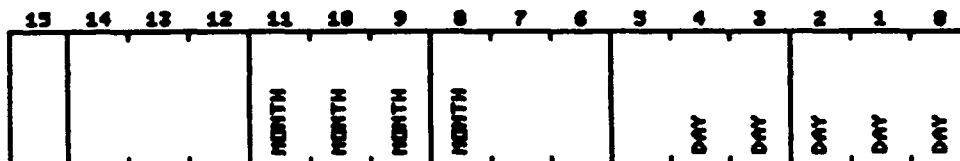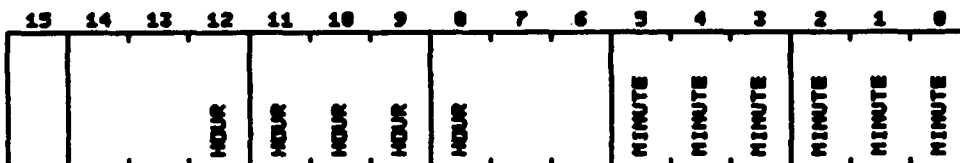
STATUS
@ 760776
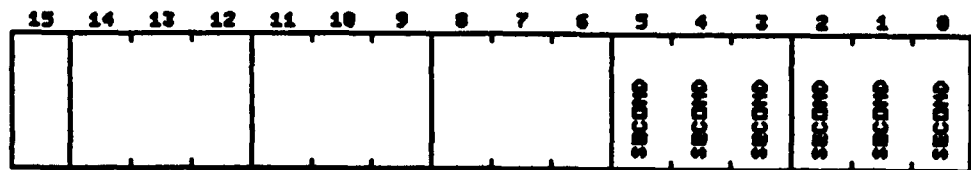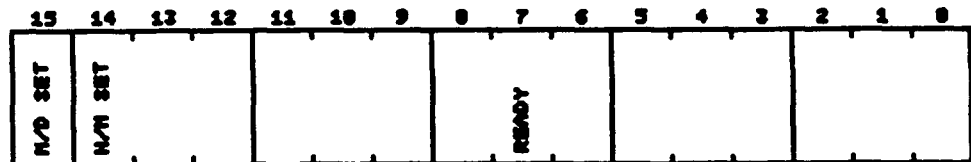
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
M/D SET	H/M SET							READY							

M/D SET	Month/day being set -- fast clock on.
H/M SET	Hour/minute being set -- fast clock on when 1.
READY	TCU ready.

TCU-50 DYR:

DATA
@ 760770

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
								DAT7	DAT6	DAT5	DAT4	DAT3	DAT2	DAT1	DAT0
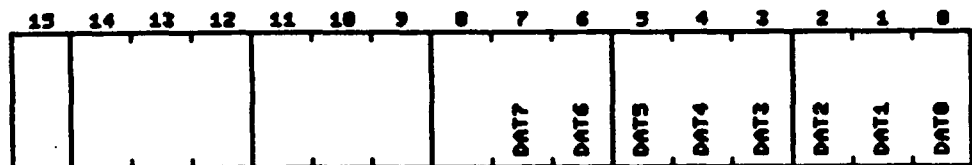
DAT7-DAT0	Read/write data bits. When reading a counter or latch register, the bits are 2 BCD numbers packed in 8 binary bits (eg. 23 = 00010011 = 0001 0011 = 13).

CTRL
@ 760772

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
			IE	WRT	CLK/RAM	RS9	RS8	RS7	RS6	RS5	RS4	RS3	RS2	RS1	RS0
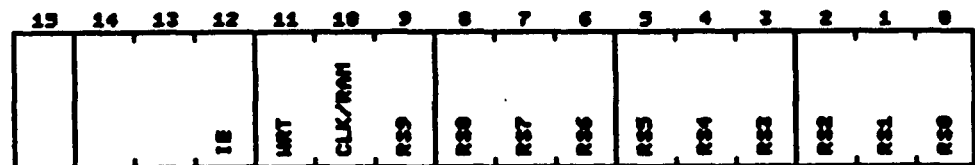
IE	Interrupt enable if switch SW3-1 is on.
WRT	Write enable -- allows writing to the clock or RAM registers.
CLK/RAM	If this bit is 0, then bits 0-4 select one of the 32 clock registers. If 1, then bits 0-9 select one of the 1024 CMOS RAM registers.
RS9-RS0	Register select:

00000	counter - .001 secs
00001	counter - .1 and .01 secs
00010	counter - secs
00011	counter - mins

```
00100          counter  -  hours
00101          counter  -  day of week
00110          counter  -  day of month
00111          counter  -  month
01000          latch    -  .001 secs
01001          latch    -  .1 and .01 decs
01010          latch    -  secs                .
01011          latch    -  mins
01100          latch    -  hours
01101          latch    -  day of week
01110          latch    -  day of month
01111          latch    -  months
10000          interrupt status register (R)
10001          interrupt control register (W)
10100          status bit
10101          GO command
10110          standby interrupt
```

Matrox QRGB-GRAPH Controller

The Matrox QRGB-GRAPH controller is a color graphics
interface for use with RGB monitors. Contained in a PROM is a
color look-up table which has been modified by Norman McCrae for
gray-scale operations. I have written general purpose software
routines to be used with the Matrox board to draw axes, point
plots, vector plots and draw characters. There are 512 x 512
pixels available but due to some flaw in the design of the Matrox
board the software only uses 256 pixels in the Y direction.
There are 11 directly accessed registers plus 14 CRTC registers
that are indirectly accessed through an address register (VECT)
and data port (CRT5). The CRTC registers will not be discussed
here -- they are used only for initialization procedures and
their use can be found in the Matrox manual. Not all mnemonics
for the directly accessible registers will be defined in this
report as they are not used in the DIAL DAS software.

```
XREG          @ 764400          X coordinate (10 bits)
YREG          @ 764402          Y coordinate (10 bits)
DATA          @ 764404          data register (4 bits)
ST1    (R)    @ 764406          preset memory status
CTR1   (W)    @ 764406          zoom/pan control
ALP    (R)    @ 764410          auxiliary light pen register
CTR3   (W)    @ 764410          color map select
CTR4          @ 764412          write plane enable
ST2    (R)    @ 764414          vertical blanking status
VECT   (W)    @ 764414          CRTC address/vector register
CTR5          @ 764416          CRTC data register/preset control
```

ST1
@ 764406

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
PREM FLG															
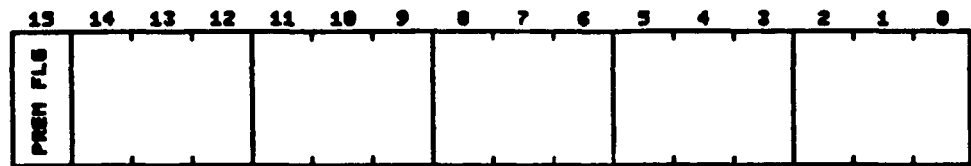
PREM FLG   If 1, memory is being preset or frame grab in progress.

CRT1
@ 764406

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
YZOOM1	YZOOM0	XZOOM2	XZOOM1	XZOOM0	XPAN2	XPAN1	XPAN0	ALTMAP	BLINKEN	FGC	DMA	IRQUEN	VDO BUS	CLIPEN	WRCPL
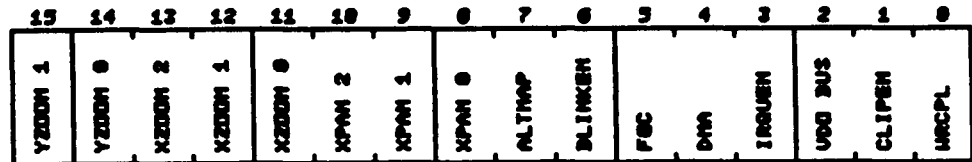
YZOOM1-YZOOM0	Y-zoom: 00 = 1, 01 = 2, 10 = 4
XZOOM2-XZOOM0	X-zoom: 111 = 1, 110 = 2, 101 = 3, 100 = 4,
	011 = 5, 010 = 6, 001 = 7, 000 = 8
XPAN2-XPAN0	Horizontal display pan delay.
ALTMAP	Selects A or B color-look-up table.
BLINKEN	When set, blinks display.
FGC	Continuous frame grab (not used).
DMA	When 1, the display memory can be accessed by DMA.
IRQUEN	Interrupt enable.
VDO BUS	Video bus enable when 0.
CLIPEN	Clipping enabled when 1.
WRCPL	Data at X,Y is complemented when 1.

VECT
@ 764414

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
			WRT AUTO	DEC Y	DEC X	INC Y	INC X	CRTC7	CRTC6	CRTC5	CRTC4	CRTC3	CRTC2	CRTC1	CRTC0
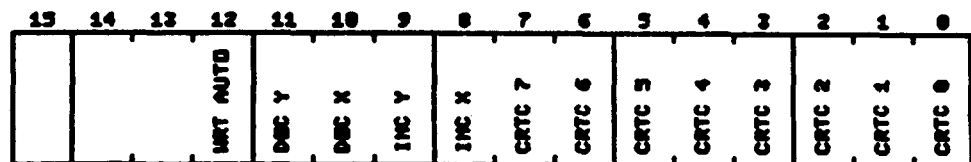
WRT AUTO	When 0, data in DATA is automatically written to X,Y when VECT is loaded.
DEC Y	When 1, auto-decrement of Y is in effect.
DEC X	When 1, auto-decrement of X is in effect.
INC Y	When 1, auto-increment of Y is in effect.
INC X	When 1, auto-increment of X is in effect.
CRTC7-CRTC0	Address of CRTC register (used only at start-up).

CRT5
@ 764416

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
PRESET	FBS					DISS	DISM	DAT7	DAT6	DAT5	DAT4	DAT3	DAT2	DAT1	DAT0

PRESET	When 1, the part of display memory appearing on the screen is preset to the value in DATA.
FGS	Frame grab control.
DATA7-DATA0	Data port to and from the CRTC registers.

JFEP-11 Front-End Processor

The JFEP-11 is a front-end processor using a J-11 chip which plugs into a Q-bus backplane. It has 256K words of dual ported memory which may be accessed through the Q-bus. The Q-bus may only access 128K of the J-11 memory at a time. The lower range or upper range of J-11 memory is selected through a bit in the Q-bus CSR. Programs for the JFEP-11 are developed, compiled and linked on the LSI computers. To load a JFEP-11 program, the program is loaded into the memory of LSI #2 with the lower r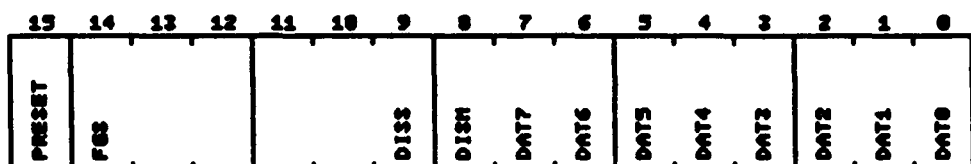ange of J-11 memory selected. To run the program on the JFEP-11, LSI #1 communicates with ODT on the J-11 board by loading the program counter register (R7) with the starting address of the J-11 program then sending a "P" which is the ODT command to proceed at the address pointed to by the program counter.

The DIAL DAS uses the JFEP-11 to perform a running average on the ozone profiles either above or below the aircraft. In order to do the running average, all shots must be maintained in memory so that one may be subtracted off the front end when a new one is added to the existing average. This requires all the memory available on the JFEP-11.

These registers are not presently used in the DIAL DAS software and are included because they will probably be used in future revisions.

@ 762004 (Q-Bus)	Q-Bus CSR
@ 777740 (J11-Bus)	J11-Bus CSR

@ 762004
Q-Bus CSR

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
SS				NXM	MEM SEL	DMA ENA	DPM DIS	VECT 7	VECT 6	VECT 5	VECT 4	VECT 3	VECT 2	VECT 1	JINT REQ

SS	Stop/Restart J-11 through power fail mode. Cleared by writing a zero or power fail acknowledged.
NXM	Non-existent memory status when accessing Q-bus in DMA mode.
MEM SEL	Selects lower memory when clear, upper memory when 1.
DMA ENA	Enables DMA transfers to Q-bus.
DPM DIS	Disables the dual ported memory from the Q-bus.
VECT	J11 vector address which gets shifted by one when sent to the J11 bus, thereby, doubling address in these bits.
JINT REQ	Generates a J11 interrupt request.

J11-Bus CSR @ 177740

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
DMA ENA	UBACK	GBQ				EVT	REQ DMA	VECT 7	VECT 6	VECT 5	VECT 4	VECT 3	VECT 2	VECT 1	QINT REQ

DMA ENA   When set, Q-bus has enabled DMA transfers. Read only.
UBACK   When clear, J11 can access Q-bus DMA controller.
GBQ   Grab the Q-bus for transfers between the J11 and Q-bus.
EVT   Used to enable the EVENT line time clock.
REQ DMA   Requests control of the DMA logic.
VECT   Vector address for the Q-bus, shifted by one.
QINT REQ   Used to generate an interrupt request to the Q-bus.

LSI 11/73 Memory Management Registers

There are many registers internal to the LSI CPU's which will not be discussed here. The registers described below are all concerned with memory management and are included in this document because they are used extensively in the DIAL DAS software. Only the bits that are used will be defined here.

PDR   @ 772300   page descriptor
PAR   @ 772340   page address
MMR0   @ 777572   memory management register 0
MMR3   @ 772516   memory management register 3

PDR @ 772300

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
BYP CAC	PLF 6	PLF 5	PLF 4	PLF 3	PLF 2	PLF 1	PLF 0								

BYP CAC   Bypass cache.
PLF   Page length field.

PAR @ 772340

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
PAF 15	PAF 14	PAF 13	PAF 12	PAF 11	PAF 10	PAF 9	PAF 8	PAF 7	PAF 6	PAF 5	PAF 4	PAF 3	PAF 2	PAF 1	PAF 0

PAF   Page address field. Address to be relocated. The
            actual address that is relocated is the PAF+00. A
            200 PAF represents an address of 20000.

@ 777572
MMR0

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
															EN REL
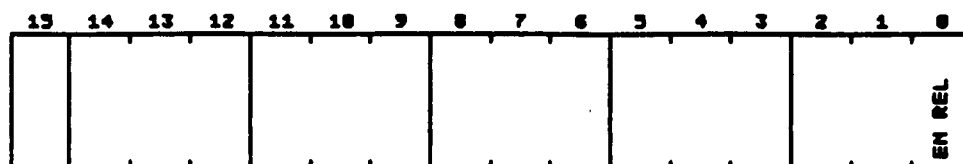
EN REL   Enable relocation when set to 1.

@ 772516
MMR3

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
											EN 22				
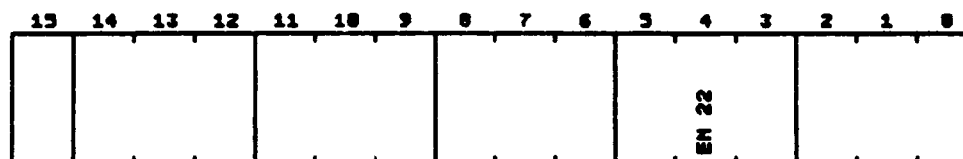
EN 22   Enable 22-bit addressing.

DIAL DAS SOFTWARE

The DIAL DAS Operating System (OS) software consists of three programs which run simultaneously on the two LSI processors and the JFEP-11 processor. The program on LSI #1 is called "MASTER" and is dedicated to data transfer and storage. The LSI #2 program is called "SLAVE" and is responsible for data analysis and display. The program on the JFEP-11 is called J11 and does the DIAL calculation on an on-line and off-line pair then performs a running average of these profiles. The user communicates with all three programs through LSI #1 which passes data buffers and display options to LSI #2 and the JFEP-11 as necessary. Figure 4 shows the interconnection among the three programs running on the three processors. During real-time experimental situations, the MASTER program gathers digitized laser signals from the Transiac 2012S's. It also gathers laser energies through a DRV11-C interface, temperatures and pressure altitude through a second DRV11-C interface, time of day from the TCU-50 DYR, and position information from the Loran or INS navigation devices through a third DRV11-C. Data acquisition is interrupt driven by the Lase Coherent Trigger into the Transiacs. After the data is packed into one continuous buffer, the record is written to magnetic tape. If LSI #2 has finished processing the previous laser shot, the new data buffer is transferred to LSI #2 from LSI #1 through a DMA interprocessor link. The on-line and off-line pair to be processed is sent to the JFEP-11 through J11 dual ported memory on LSI #2. The CRT display rate in real-time depends on the amount of data to be plotted and on the complexity of the data analysis to be performed. For example, at 5 Hz laser firing, 8192 words of raw data from one unit (no analysis) will be viewed every fourth shot. Real-time profiles of ozone or water vapor concentrations are updated every fifth shot. These displays of raw and processed DIAL information allow for real-time system optimization as well as flight path decisions during flight operations. Display rates on the two ACT II printers are governed by operations on their respective processors. The range-squared aerosol color maps are performed by LSI #1 and we typically do a 15 shot average (or 3 seconds) before plotting so there is plenty of time to catch each shot, i.e. a 15 shot average represents 3 uninterrupted seconds of data. On the other hand, when we use LSI #2 and the JFEP-11 to perform our running average of ozone plots to the color printer, plotting time (which is done by LSI #2) must be shared with CRT data display and analysis. Depending on the complexity of CRT display, a 60 shot running average may represent a 2 minute or more display in time.

Data transfer operations from the digitizing units are readily accomplished within the minimum 100 ms operation time envelope between laser firings. The lase-coherent time base is designed to key the digitizers to sample for 136.3 usecs (1363 words) of the on-line lase then to go into a "sleep" mode until the off-line lase at which time it restarts the sampling (ref. 3). This avoids the necessity of digitizing long records to acquire the on-line return followed by the off-line return 300 usecs later. Since both sampling intervals are triggered by the
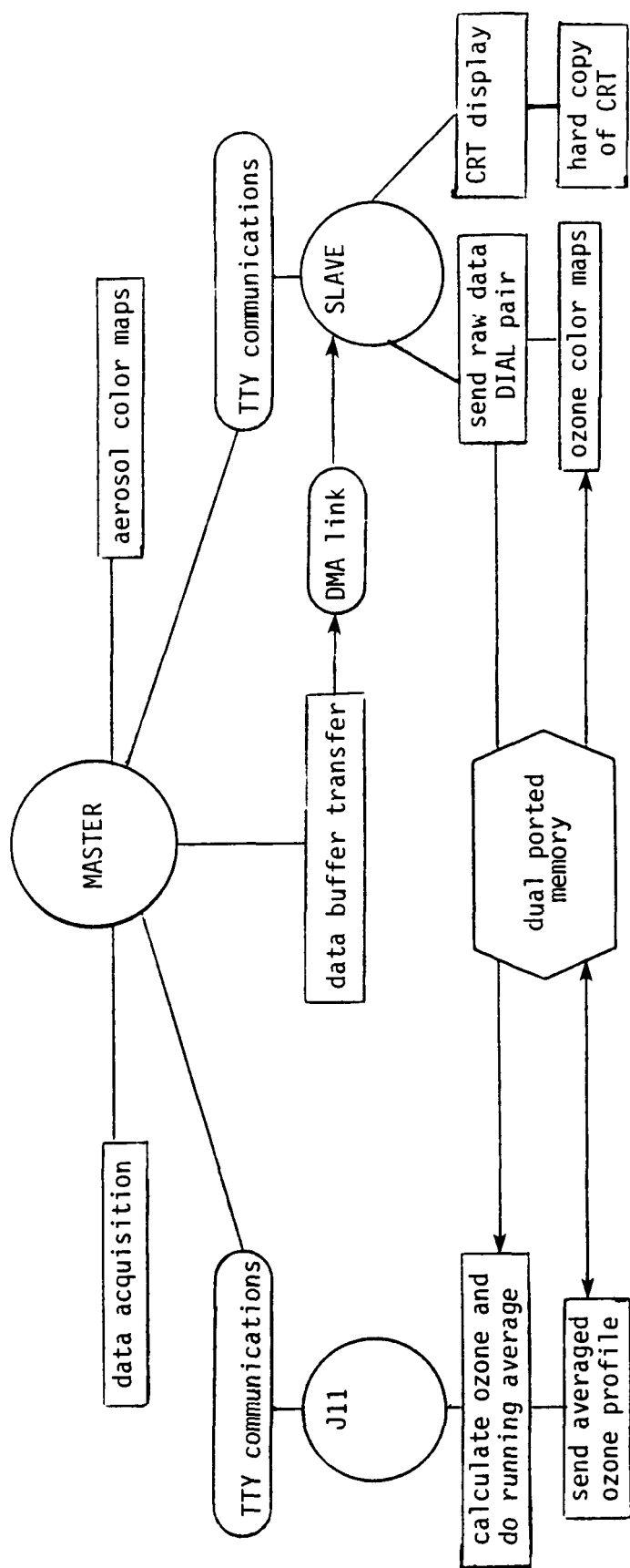
Figure 4. DIAL DAS program interconnections.

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actual firing of the lasers through optical sensors, there is more stability of word alignment between the on and off-line returns. Software commands are available which control the starting points and number of words for data storage for each signal return. The maximum buffer size is presently set at 8192 words. The combined data stored from all the digitizers in use plus the shot header information must not exceed 8192 words.

Getting Started

Since the teletype is interfaced to LSI #1, a short program is available on each of the system diskettes which allows the user to communicate directly with LSI #2. Once LSI #1 is booted, type "R LSI2" to access LSI #2. Thereafter, each character is sent through the serial line interface to LSI #2. Similarly, there is a program on each system diskette called JFEP to communicate with ODT on the JFEP-11.

Jumpers have been selected on both LSI's to boot up from disk to RT-11 on power up. To run the MASTER and SLAVE programs, LSI #2 must start out in RT-11. This allows program MASTER to run program SLAVE. The procedure to start up the MASTER/SLAVE programs is outlined below. System diskettes with the RT11 monitor on them have blue labels. The diskettes with the programs "MASTER" and "SLAVE" have yellow labels.

1.   Place system diskettes (blue) in drive 0 of both disk drives.
2.   Place MASTER (yellow) in drive 1 of LSI #1 and SLAVE (yellow) in drive 1 of LSI #2.
3.   Make sure both systems are running RT-11 by pushing the DC ON buttons on both chassis then waiting for the RUN lights to come on and stay lit.
4.   Run program MASTER by typing: RUN MASTER
5.   MASTER will load and in turn call SLAVE. LSI #2 is ready when "MATROX" is visible on the video display.   LSI #1 is ready when the default banner record is printed out on the console display.
 6.   You are now under the DIAL DAS OS. Anything you type in from now on will be interpreted by program MASTER. To return to the monitor use the instruction KILL. To return to ODT hit the BREAK key.
7.   To erase one character hit the "backspace" key.   To erase a whole line hit the DEL key.
8.   Valid instructions are listed in the section "Keyboard Commands".
9.   If LSI #1 bombs, start back at step 3.
10. If LSI #2 bombs to ODT (indicated by "@"), then type BOOT. If LSI #2 bombs to Monitor (indicated by RT-11 error message), type SLAVE.
11. If the display on LSI #2 stops updating, use the SYNC command.

The user now has the capability to fully control data buffering and recording, as well as many other aspects of data analysis and display. A sample user dialogue is given at the end of the section "Keyboard Commands". Comments are made on each line to describe what the user is doing (those preceded by two

hyphens) or what action the computer is taking (comments in parentheses). Commands marked "--*" have arguments which are already program defaults so they did not need to be entered. They are included to demonstrate the use of these commands.

Data Acquisition

Data acquisition is controlled by hardware switches on the digitizing units and by keyboard commands. On the Transiac 2012S a knob setting selects the number of pre-trigger samples in increments of 1/8 of the total record (a selected record length of 4096 words would have pre-trigger increments of 512). A certain number of pre-trigger samples are desirable (about 10 to 20) to provide a good window for the trigger marker but certainly not all 512 of the Transiac pre-trigger words need be saved. There is also the case where a unit is used to digitize only an offline return which occurs some time after that unit was triggered. Only the data from the second return need be saved. The instruction " STORE U1,U2,U3,U4" determines the starting word for each unit at which data is to be saved. For those units storing two returns (both online and offline), the first return is saved starting at Ui and the second return is saved starting at Ui + 1363, i = 1, 2, 3, OR 4. The number of words saved of the first return for each unit is determined by the instruction "WORDS1 U1,U2,U3,U4". Similarly, "WORDS2 U1,U2,U3,U4 specifies the number of words to store of the second return of each unit. The separation between the on and off-line returns has varied from one mission to another so the command "WAKEUP I" can be used to change the value from 1363 to a suitable value. The word number for the "wakeup" can be determined by listing out words of the on-line return and off-line return, determining where the trigger markers are and then adding or subtracting from the existing value to make the two trigger words fall at the same word.

The laser shots can be internally averaged by the Transiac 2012s and 4100. Hardware averaging is a necessity at 10 Hz operations for buffers of 8192 words. The number of shots to average can be selected by the command "DATAVG U1,U2,U3,U4". Each unit should be set to average the same number of shots except when in "STACK" or "TWEEK" modes. The maximum number of shots that can be averaged without overflowing the 16-bit interger is 15. Thus far, we heve used a 5 shot (or 1 Hz) averaging option. For most cases, the 1 Hz resolution is more than adequate for our experimental objectives but at times there is a need to obtain a finer resolution of the visible aerosol data. Rather than an increasing storage rates of all digitizing units to a 5 Hz resolution (thereby increasing the amount of data stored by a factor of 5) a special set-up is provided for where the last unit to be sampled can be stacked in memory at the end of the buffer at a different rate than the other three units. There are two restrictions on the use of this procedure. The stacked unit must be the last unit and the resolution of the stacked data must be 5 Hz. Thus, for a 5 Hz laser repitition rate the command "DATAVG 5,5,5,1" and for a 10 Hz rate, the command "DATAVG 10,10,10,2" are valid stacking set-ups (see figure 5). An example of data acquisition will be given at the

Figure 5. Stacked data buffer format.

end of the section "Keyboard Commands".

Real-Time Data Display

All data processing and display to the video screen are performed by the SLAVE program on LSI #2. LSI #1 is reserved for data transfer from the digitizers, for magnetic tape operations, and for console keyboard communications. However, on request, LSI #1 will produce real-time color representation of range resolved profiles on the Act II printer. On LSI #2, four basic modes for DIAL data display are available, each with a variety of display options. At the same time several other pieces of information can be shown on the right hand side of the screen. Altitude, temperature data and laser energies from the DRV11-C interfaces can be viewed. Certain hook-up conventions must be observed for the DRV11-C input in order to get default conversion constants and labeling to correspond:

DRV11-C Channel (@50)	Input	Label	Units
1	aircraft altitude	ALT	ft
2	dewpoint temperature	DPT	C
3	temperature	T	C
4	total temperature	TT	C

DRV11-C Channel (@60)	Input			Label	Units
1	online UV	laser	energy	UVN	MJ
2	offline UV	"	"	UVF	MJ
3	online IR	"	"	IRN	MJ
4	offline IR	"	"	IRF	MJ
5	online VIS	"	"	VISN	MJ
6	offline VIS	"	"	VISF	MJ

The DIAL DAS command language allows the user to input a slope and intercept to the banner record for each DRV11-C channel to convert the digitized counts to the units shown above. Conversion constants must be input as integers. So each slope and intercept is represented by an integer mantissa and corresponding exponent of 10. These four words per conversion channel are stored in the banner record. The user also has options to update the plot side of the screen (left) by itself, update the right side by itself, or both sides at the same time (UPDATE command).

When the data is being hardware averaged by the digitizers, update of the CRT display is limited to the effective rate of the averaged data. In some cases, a faster update may be necessary so a "TWEEK I" command has been included where unit I will by-pass internal averaging to allow for tweeking or optimizing of signals from that unit. To return to normal operations type

"TWEEK 0".

The different display options are summarized on the next page. Each display mode has a number of default options associated with it. These are summarized in table 5. The default values can be changed by various keyboard commands. Display options are available for background subtraction, range-square correction, over-laying data of different digitizers, scale and more. Each display option can be activated or de-activated in real-time to observe signal features in the most useful format.

Table 5. Default plotting parameters (troposheric set-up).

PARAMETER	MODE 1	MODE 2	OZONE	COMMAND
unit select	all	all	UNIT1	UNIT
y-axis scale	0-4096	0-4096	0-800	SCALE
x-axis scale	all data	150m/tic	150m/tic	INDEX
background word	550	550	550	BGWORD
background window	50	50	50	BGWIND
smooth	no	300m	300m	SMOOTH
average shots	no	no	300	PLTAVG
range cell	---	---	300m	RNGCEL
gas exponent	---	---	-10	GASEXP
atmospheric correction		---	yes	ATMCOR
Rayleigh correction		---	-6.7 ppb	RAYCOR
shift toa	---	no	no	SHFTOA
update right screen	yes	yes	no	UPDATE

Raw Data (MODE 1)

This is the basic display mode which presents raw data from each of the digitizing units as it exists in computer memory (figure 6). The abscissa represents word sequence in memory while the ordinate is adjusted to present the 12-bit signal magnitude with variable magnification. The one word instruction "MODE 1" calls up all the options listed as defaults in table 5.

Online/Offline Overlay (MODE 2)

A second display mode presents the raw data signals in an overlapped format. As shown in figure 7, the online and offline return signals from each unit are overlayed. Units 1 and 2 represent UV returns in the nadir and zenith directions respectively. Unit 3 shows the 1060nm aerosol returns -- the zenith and nadir returns have been summed with an analog switch to enable us to digitize with only one unit. Unit 4 shows the 600nm aerosol returns --again these returns have been summed. By default, each of these returns have been smoothed over 300m and plotted as a function of time, each tic mark representing 1 usec. Each data shot is plotted in this mode starting after
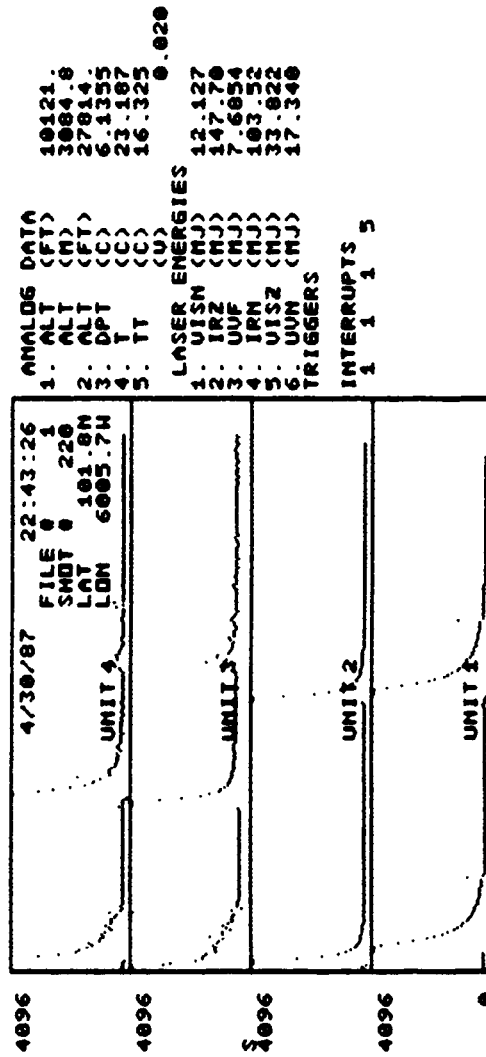
Figure 6. Example of MODE 1 display. Copied to ACT II printer with COPY -1 command.
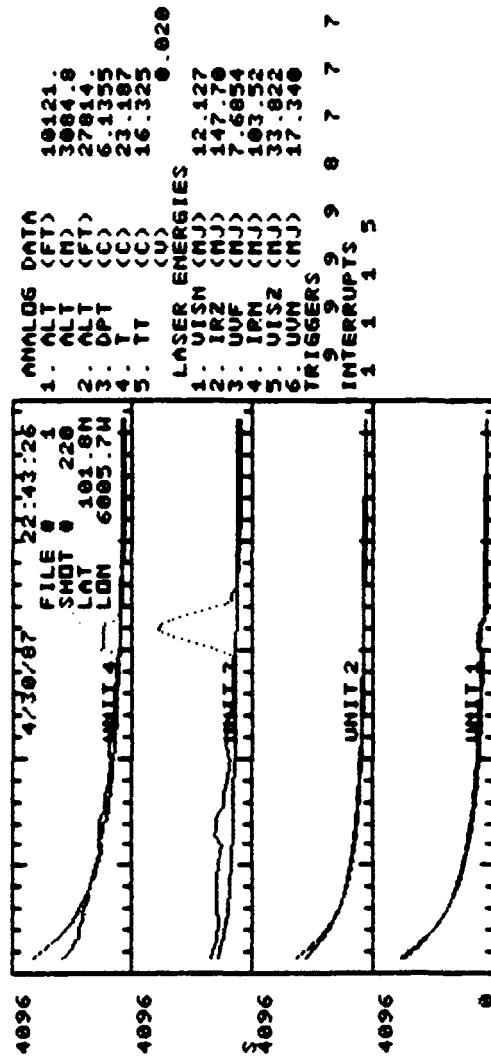
Figure 7. Example of MODE 2 display.

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the PMT gate delay. In this mode a search is also performed for
a trigger position to line up each of the returns with respect to
the laser firings.   This trigger position word number is
displayed on the right hand side of the screen.   The user
specifies the trigger ordinate level to be used for each
digitizer unit along with the number of words it is nominally
delayed.   The lase-coherent trigger markers are electronically
delayed 14 words from the actual laser firing but a breakthrough
pulse occurs at the same word as the laser firing.
     Figure 8 shows the effect of activating the background
subtraction and range squared options on the profile of UNIT1 in
figure 7 (MODE 2).   Display of the data in this mode allows us to
more readily see the differences in the absorbed on-line return
as compared to the off-line return.   Figure 9, again shows the
effect of activating the subtraction and range squared options.
This time the on-line returns of units 3 and 4 have been selected
and the overlay option is turned on.   From this display we can
easily see the response of the two different aerosol wavelengths
used -- one being more sensitive to the molecular content of the
atmosphere.   The sequence of instructions to obtain figure 9 is
as follows:

          MODE 2
          RETURN 0,0,1,1
          OVRLAY 1
          RNGCOR 1
          YMAX 8192

Gray-Scale Display (GRYSCL)

     A 16 level gray scale display format is available for
presentation of the spatial distribution of aerosol scattering
In processing the aerosol lidar return, the background signal
level is subtracted from the lidar-plus-background signal and
the geometrical range squared lidar signal dependence is
eliminated.   The resulting lidar backscatter profile is
indicative of the distribution of aerosols along the lidar line-
of-sight.   The vertical resolution of the aerosol data is 15 m.
The nominal horizontal resolution is 10 m for aircraft operation
at a 10 Hz repetition rate.   The backscatter signal level is
converted into a 16 level gray scale display line where stronger
scattering is indicated by higher brightness on the monitor or
a darker dot pattern on the printed version of the display.
Sequential gray scale lines are used to construct a real-time
picture of the aerosol vertical distribution along the Electra
flight path.   Each of the gray scale displays can contain 300
individual or integrated aerosol profiles.   At a laser pulse
repetition rate of 1 or 10 Hz, the 300 individual profiles
correspond to a nominal horizontal traverse of 30 or 3 km,
respectively.   This horizontal scale assumes a nominal ground
speed of 100 m/sec for the Electra aircraft.   The gray scale
format shows the terrain profile, and it clearly identifies the
distribution of aerosols in the boundary layer and the free
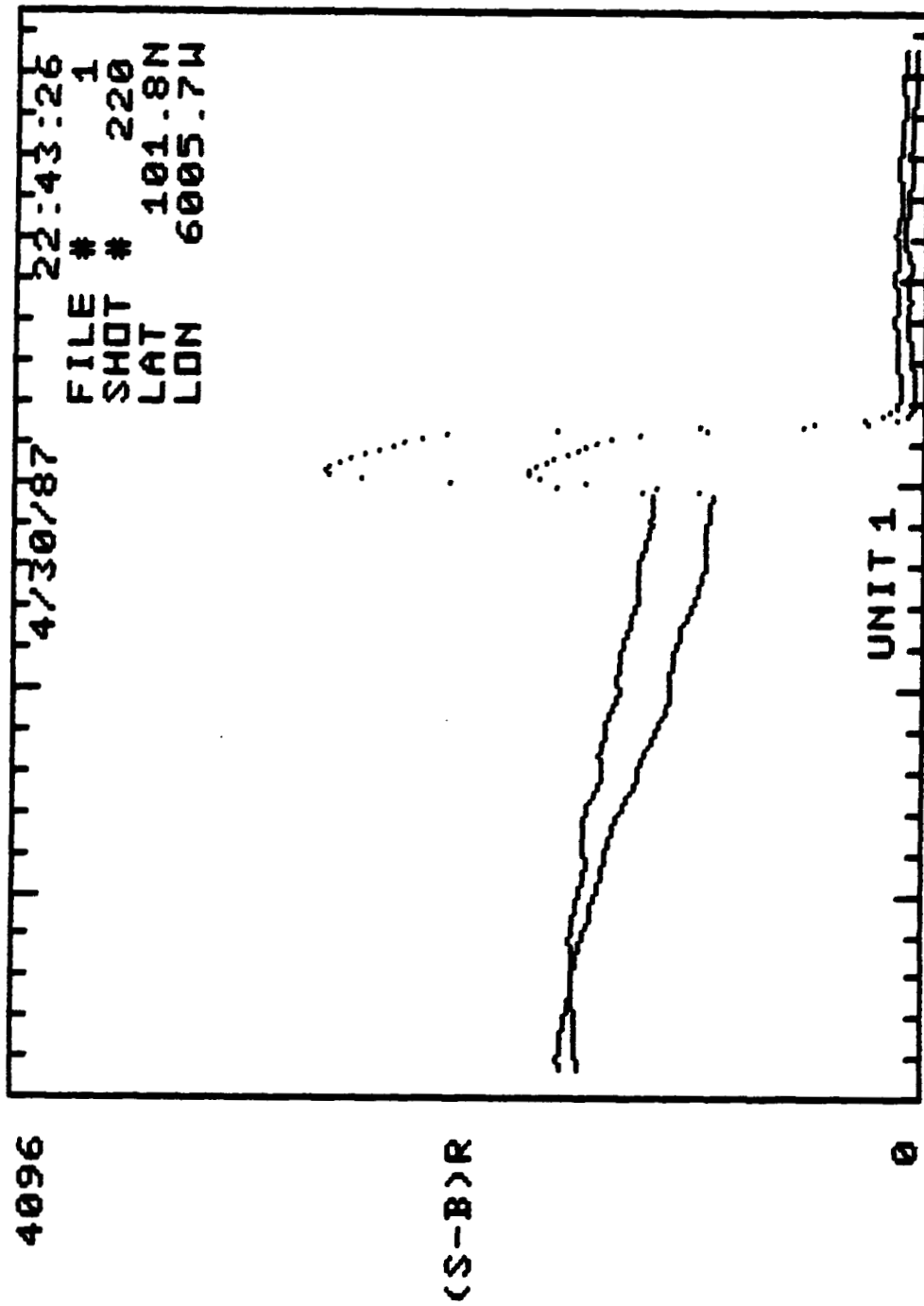
Figure 8. MODE 2 display with background subtraction and range-squared options in effect on DIAL pair of UNIT 1. Difference in slopes indicates absorption by ozone.
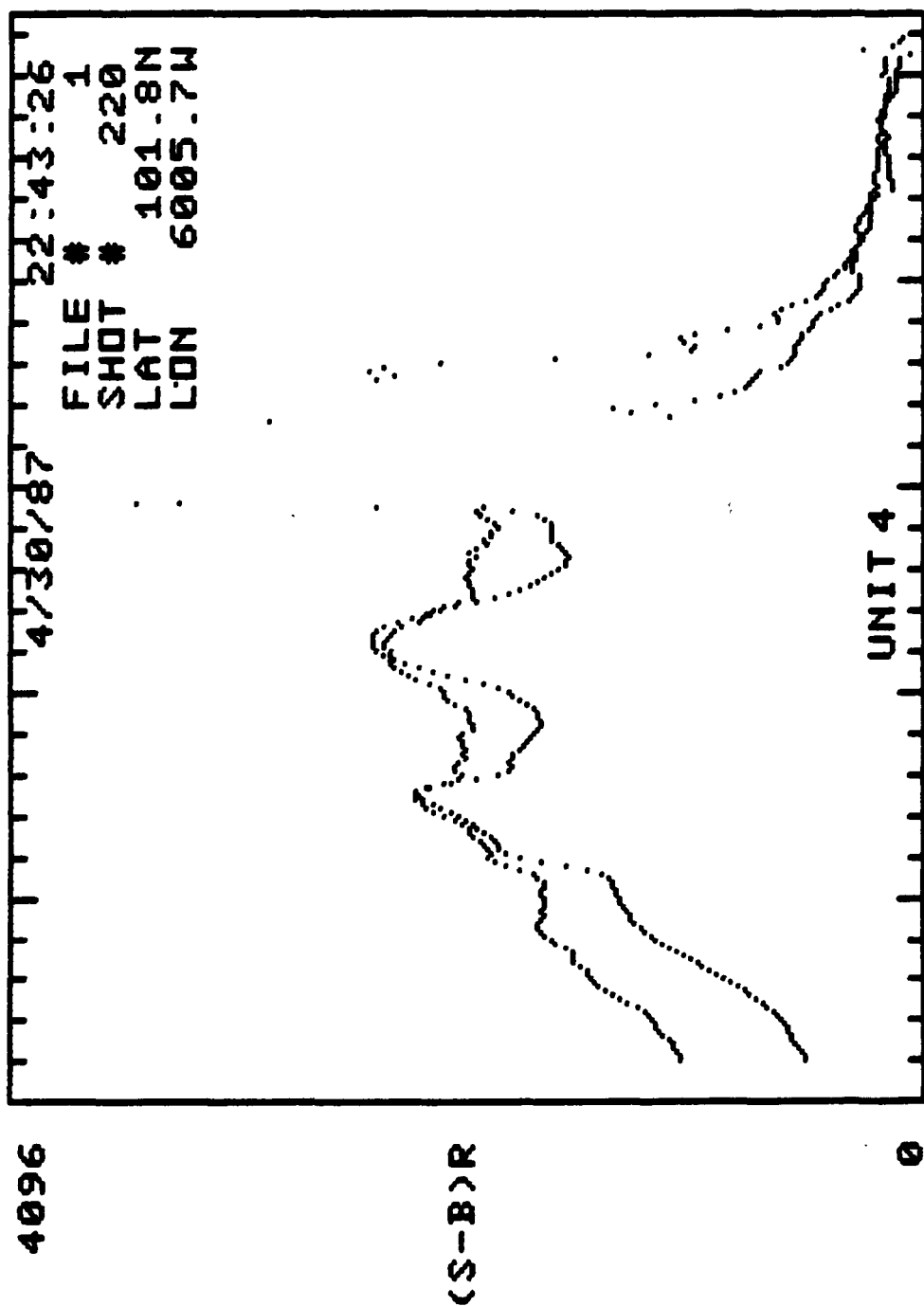
Figure 9. MODE 2 display of the online returns of units 3 and 4 with background subtraction, range-squared and overlay options in effect.

troposphere.   Since the addition of the ACT II printers to the
system,   this operation is performed hardcopy and in color on one
of the printers and rarely used as a CRT mode of display.

Concentration Profiles (OZONE)

        This display mode presents the gas concentrations as a
function of altitude or range calculated from the DIAL signal
pair (figure 10).   For each DIAL return, the background signal
level is integrated over a specified interval.   The starting
point of this integration is selected by the command "BGWORD" and
the number of words to average over is specified by "BGWIND".
This average background is subtracted from the return signal, and
the resulting data is then smoothed with a running mean over the
specified range interval (see "SMOOTH").   This   smoothing
technique does not introduce errors only for those atmospheric
conditions where the aerosol scattering is not changing rapidly
along the DIAL measurement path.   The DIAL equation (ref. 1) is
evaluated using the smoothed lidar returns over a specified range
cell size, usually 300 m.   Ozone concentrations are determined
for each range cell and finally, the Rayleigh extinction is
corrected for altitude and subtracted.   The Rayleigh term is to
compensate for extinction differences between the on and off
lines.   Each DIAL signal pair produces a concentration profile.
Ozone profiles are plotted as concentrations for startospheric
work and mixing ratios for troposheric work.   To obtain the
mixing ratios, an approximation to the molecular number density
is divided into the concentration at each range cell. Any number
of DIAL measurements can be averaged together to improve the
profile statistics at the expense of increased horizontal
integration for the measurement.   The standard deviation for the
resulting averaged profile is computed at increments equivalent
to the range cell size and displayed on the concentration
profile.
        The commands UNIT, BGWORD, BGWIND, RNGCEL, SMOOTH, PLTAVG,
GASEXP can all be used to change the defaults to modify the
display or to better improve the resulting calculations.   These
and others that can be used are listed in the section "Keyboard
Commands".   The command SHFTOA which applies only to ozone
calculations is a diagnostic tool to shift one DIAL UV pair with
respect to the other.   This command will be further discussed in
the section titled "DIAL Pair Alignment".

Hard Copy Aerosol Color-Scale Map (MAPAER)

        This option represents the same type of display as described
for "GRYSCL"; however, it is done in color on the ACT II printer.
When this option is activated, the current banner record and
MAPAER plotting parameters are printed followed by a 25 shade
color scale display of relative aerosol concentrations.   The
color scale which follows the color spectrum is shown at the top
of each plot.   White is on the low end of the scale and black is
on the high end.   The user specifies a minimum value below which
all data will appear as white ("WHITE") and a maximum value above

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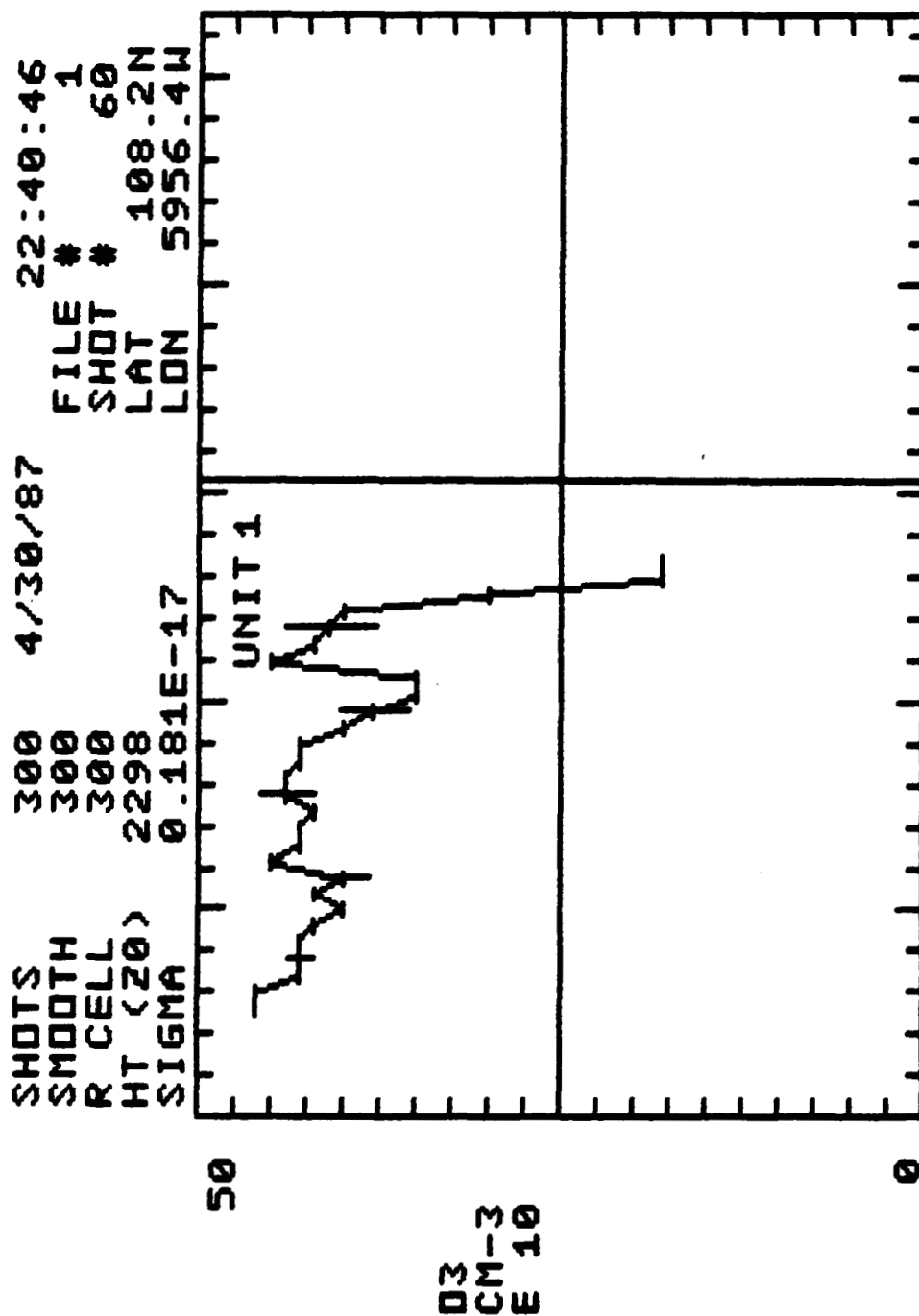
Figure 10. Example of OZONE display (300 shots averaged).

which all data will appear as black ("BLACK"). Data shots may be averaged (up to 15 shots) or plotted individually. Additionally, data may be vertically smoothed with a running average. The nadir data can be shifted for altitude variations using the information in the shot header if the ALTCOR option is used. During real-time operations the computer can plot about one profile a second (either averaged or individual). Time, latitude and longitude are printed at specified minute markers. The hard copy continues until turned off with the instruction "AEROFF" or whenever any of the MAPAER plotting parameters are changed. The user must re-start with "MAPAER" after changing plotting parameters. This allows the new plotting parameters to be printed so that an updated record is always available.

Hard-Copy Ozone Color Scale Map (MAPUV)

On and off-line pairs of data are sent to the JFEP-11 through the shared memory on LSI #2 and ozone concentrations similar to those discussed above (CRT display mode) are calculated. Each concentration profile up to some specified average is stored in the JFEP memory. When a total number of profiles for the average has been stored, a new profile will be added on to the end for one that is subtracted off the beginning to form a running average. All options discussed in the section concerning the CRT ozone display also apply to the hard-copy displays but must be preceded by the symbol *. Each single ozone profile can be shifted in the array to compensate for variations in aircraft altitude using the information in the shot header (nadir mode only). Additionally, cloud returns can be detected and computations will be performed as far as the cloud using the CLOUD I parameter. A value of CLOUD 2 will pick up weak clouds and a value of CLOUD 4096 will ignore clouds altogether.

Figure 11 shows sample aerosol and ozone color maps using the MAPAER and MAPUV commands.

Magnetic Tape Storage and Format

The DIAL data is stored in real-time using one of two Cipher tape drives. This allows for constant recording of data while one unit is rewinding. The data is recorded at 100 ips in "streamer" mode. Streamer mode is the only method we found to record the 8K blocks of DIAL data at 10 Hz operation. The disadvantage of streamer mode is that if the tape unit does not get a new instruction within a small period of time it requires a long repositioning time. The DIAL DAS software was written so that each data transfer from the digitizers is stored in a consecutive block of extended memory -- up to 11 blocks are available (for non-stack operation). Once transfer to the top block (@ 740000) is done data transfer continues to the bottom block (@ 200000). When a request is made to commence recording data, the first available block is transferred to tape as soon as the tape has repositioned. During repositioning time other data blocks will be stored in memory and these are queued as they come along. As soon as the tape is again ready it is given the next queued block to record. This procedure produces a streaming
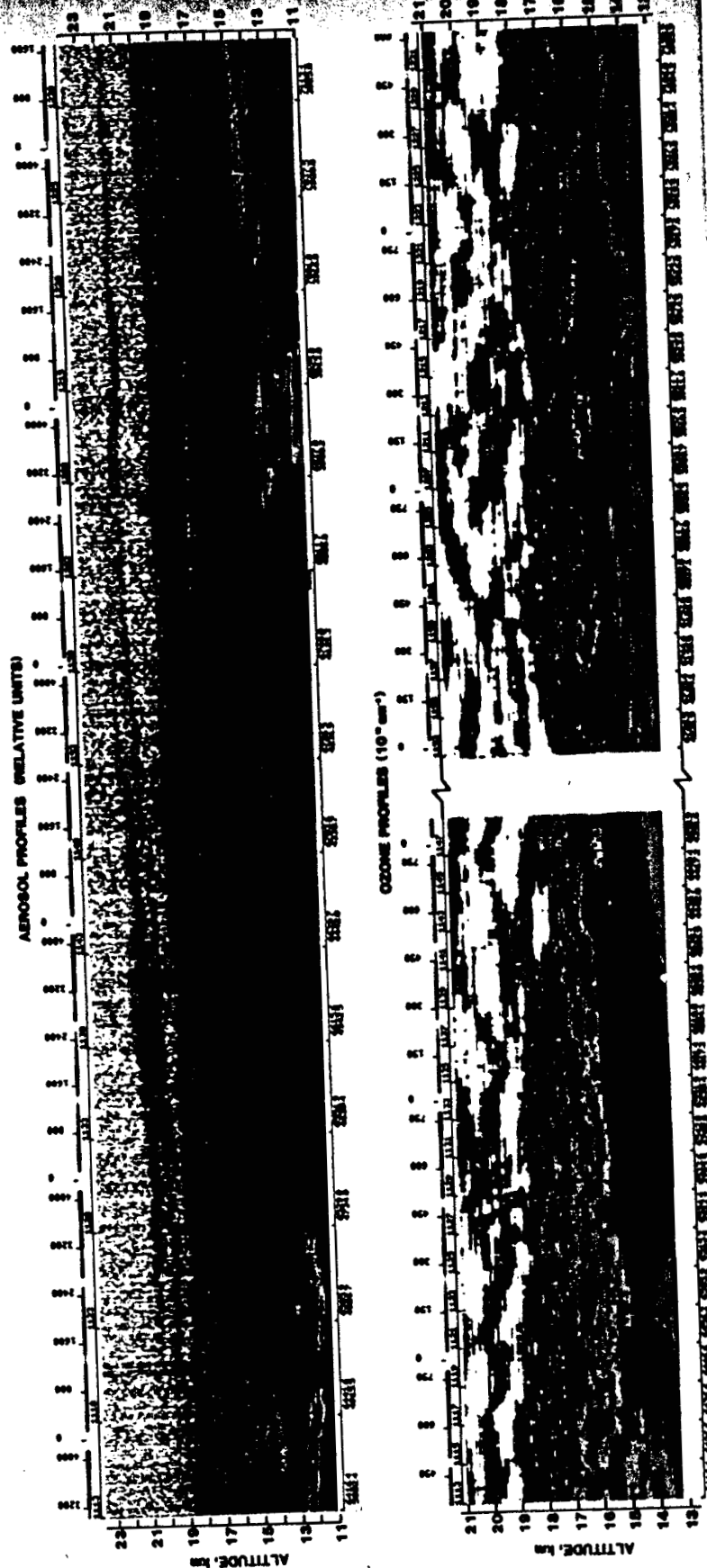
Figure 11. Photograph made of real-time aerosol (MAPAER) and ozone (MAPUV) color maps. Prints are 15% of original size.

operation with minimal need to reposition. Tests show that 4k
blocks are written to tape at 10 Hz with upto 10 blocks getting
queued, at 5 Hz 5 blocks get queued and at 1 Hz no blocks get
queued.

Data is written using 1600 bpi PE magnetic tape format on
2400-ft reels of .5 in wide magnetic tape. Each data storage
file begins with a 256 word banner record (16 bits per word) with
DIAL DAS information as shown on table 6. The data from each
laser shot is packed into one large record on magnetic tape (data
from all digitizer units are packed into one single buffer).
Each data record begins with a shot header of information
required on a shot-by-shot basis. This includes time, shot
number, latitude, longitude, altitude, temperature data, and
laser energies. The number of words in the header is currently
30 but this number can be changed with the instruction "HDRPTS".
Table 7 shows the structure of a typical data record. At the end
of the tape or at the end of the information stored on that tape
there are 2 file marks (EOF) to denote end of information.

While recording data, if one tape drive reaches an end of
tape marker then it will automatically back up two records, write
two EOF's, start rewinding the tape, and start recording a new
file on the alternate tape drive.

Table 6. Banner record word assignments (dimensioned 256).

Word	Description
1	banner record format
2	tape #
3	file #
4	# words in shot header
5	date
6	plane altitude (feet) (x10 when value is negative)
7	up/down mode (0=down; 1=up)
8	sampling frequency (MHz)
9	laser fire word #
10	laser rep rate (Hz)
11	absorption coefficient (mantissa)
12	absorption coefficient (exponent)
13	wakeup value
14-16	spares
17	words/return #1 unit 1
18	words/return #1 unit 2
19	words/return #1 unit 3
20	words/return #1 unit 4
21	words/return #2 unit 1
22	words/return #2 unit 2
23	words/return #2 unit 3
24	words/return #2 unit 4
25	starting storage word unit 1
26	starting storage word unit 2
27	starting storage word unit 3
28	starting storage word unit 4
29	baseline unit 1
30	baseline unit 2
31	baseline unit 3
32	baseline unit 4
33	direction and magnitude of trigger marker unit 1
34	direction and magnitude of trigger marker unit 2
35	direction and magnitude of trigger marker unit 3
36	direction and magnitude of trigger marker unit 4
37	shots to accumulate unit 1
38	shots to accumulate unit 2
39	shots to accumulate unit 3
40	shots to accumulate unit 4
41	post-trigger delay (usecs) unit 1
42	post-trigger delay (usecs) unit 2
43	post-trigger delay (usecs) unit 3
44	post-trigger delay (usecs) unit 4
45	species identifier (RAD50) unit 1
46	species identifier (RAD50) unit 2
47	species identifier (RAD50) unit 3
48	species identifier (RAD50) unit 4
49	trigger marker delay (words) unit 1
50	trigger marker delay (words) unit 2
51	trigger marker delay (words) unit 3
52	trigger marker delay (words) unit 4
53-64	spares

```
65-104      ALT and TEMP calibration constants for channels 1-10
            4 words per channel (slope mantissa, slope exponent,
            intercept mantissa, intercept exponent)
105-144     Energy monitor calibration constants for channels 1-6
            4 words per channel (same as ADV11-C constants above)
```

Table 7. Data record structure for shot buffers.

Word #	Description
1	shot number
2	stack/nostack indicator (1=stacked)
3-4	time of day
5-6	unused
7	latitude (low order)
8	latitude (high order)
9	longitude (low order)
10	longitude (high order)
11	pressure altitude
12	radar altitude
13	dew point temperature
14	surface temperature
15	total temperature
16	Gregory Ozone
17-20	spare DRV11-C channels
21	online UV energy
22	offline UV energy
23	online IR energy
24	offline IR energy
25	online visible energy
26	offline visible energy
27-30	spare energy monitor channels
31	# shots averaged unit 1 (same as IBAN(37))
32	# shots averaged unit 2 (same as IBAN(38))
33	# shots averaged unit 3 (same as IBAN(39))
34	# shots averaged unit 4 (same as IBAN(40))
35	# interrupts received from unit 1
36	# interrupts received from unit 2
37	# interrupts received from unit 3
38	# interrupts received from unit 4
39-40	spares

The above constitutes the existing shot header.   After this
data the record buffer will contain the data stored from the
various digitizers.   The banner record whose values were defined
in table 6 (IBAN) determines the storage of data:

```
        if   L=IBAN(4),M1=IBAN(17),M2=IBAN(18),M3=IBAN(19),M4=IBAN(20)
                  N1=IBAN(21),N2=IBAN(22),N3=IBAN(23),N4=IBAN(24)
          then the data is located in the buffer as follows
```

start word #	end word #		contents
1	L		shot header
L+1	L+M1		Unit 1 data (online)
L+M1+1	L+M1+N1	= K1	Unit 1 data (offline)
K1+1	K1+M2		Unit 2 data (online)
K1+M2+1	K1+M2+N2	= K2	Unit 2 data (offline)
K2+1	K2+M3		Unit 3 data (online)
K2+M3+1	K2+M3+N3	= K3	Unit 3 data (offline)
K3+1	K3+M4		Unit 4 data (online)
K3+M4+1	K3+M4+N4		Unit 4 data (offline)

if data is stacked, there will follow another 4*(M4+N4) words
of unit 4 data (see figure 5).

Decoding Information

This section provides information necessary to decode and
convert various information in the banner (IBAN) and shot header
(IBUF).

DATE   IBAN(5)

```
bit:        14    10 9     5 4     0
            month     day     year        (binary)
```
To get the actual year, add 1972 to the value in bits 4-0.

TRIGGER MARKERS   IBAN(33)-IBAN(40)

The two high order bits indicate the logical operator: less than
is signified by a value of 1; equal to by a value of 2, and;
greater than by a value of 3. The lower 14 bits indicate the
magnitude of the comparison to be made.

GAS SPECIES   IBAN(45)-IBAN(48)

Radix-50 values are stored, up to three charcters per word, by
packing them into single numeric values according to the formula:

$$((i * 50 + j) * 50 + k$$

where "i", "j", and "k" represent the octal code values:

```
        Space           0
        A - Z           1-32
        0 - 9           36-47
```

TEMP and ALT   IBAN(65)-IBAN(104)
                                                IBUF(11)-IBUF(20)

The banner record contains the conversion constants for the
DRV11-C channels which are read in on a shot by shot basis and
stored in the shot header.

```
        counts = IBUF(10+ICH),    where ICH = channel #
        volts = counts * (10v/4095 counts)
and conversion to desired units is accomplished by:


        volts*IBAN(65+I4)*10**IBAN(66+I4)+IBAN(67+I4)*10**IBAN(68+I4)
where I4 is 4 * (channel # -1).
```

ENERGY MONITOR DATA   IBAN(105)-IBAN(144)
                                                   IBUF(21)-IBUF(30)

As in the preceding data, the conversion constants are stored in
the banner record and the laser energies are stored on a shot by
shot basis in the shot header. The values in the header are
2's complement binary counts which have been calibrated to read
in millivolts. To convert to millijoules:

```
        IBUF(20+ICH)*(IBAN(105+I4)*10**IBAN(106+I4))
                  +IBAN(107+I4)*10**IBAN(108+I4)
where ICH is the channel  and I4 = 4 * (channel # -1).
```

NAVIGATION DATA   ,   IBUF(7)-IBUF(10)

Latitude and longitude are each 2 16-bit word integers coded in
BCD. Bits 7-0 of the low order word are labels (latitude label
in hex is 10 and longitude is 90). The information is then
stored in bits 15-8 of the low order word and bits 13-0 of the
high order word with .1 min resolution. Bits 14 and 15 of the
high order word designate east, west, north or south .
Some examples:

```
                    IBUF(8)            IBUF(7)
     N8125.8    0000 1000 0001 0010 0101 1000 0001 0000
                    IBUF(10)           IBUF(9)
     W16637.8   1101 0110 0110 0011 0111 1000 1001 0000
     E07654.1   0000 0111 0110 0101 0100 0001 1001 000
```

DIAL Pair Alignment

     It has been found that it is extremely important to precise-
ly line up the on and off line returns. Even a one word offset
can cause oscillations in the concentration profiles. Therefore,
a discussion of data alignment follows. The trigger markers
provided by the lase-coherent time base are electronically
delayed from the actual laser firing so that any noise due to
flash lamp firing will not mask the markers. These markers are
the most accurate so they are used for the DIAL type returns.
There are no trigger markers available for the one-wavelength
returns so either flash lamp noise, or a breakthrough spike as
the signal hits the aircraft window, or in the case of the 1.06
return where the diode detector is always on the return itself
can be used to line up these returns with the DIAL returns. These
types of markers occur at the time of laser firing. The first
step should be to attempt to line up the on and off-line pair as
it is read in from the digitizers. Plug the trigger markers into
the first unit and note the word at which these occur in both the

on and off line returns. This is done by listing out the first 50 words of each return (e.g. LIST -1,50 and LIST -601,650). If there is any offset of the trigger markers, stop data transfer and adjust the WAKEUP value to line up the offline return with the online. For example, if the current WAKEUP value is 1363 and the offline trigger marker occurs one word earlier than the online trigger marker, a new WAKEUP of 1362 will properly align the returns. If there were no "jitter" in the timing of the two returns this would be all that would be necessary. The ABLE2B data was found to be very stable, in fact, no change was detected throughout the 6 weeks of the experiment. On the other hand, the Ozone Hole data showed three changes in the separation during the various flights. In order to eliminate any doubt, trigger search routines can be used to line up the returns on a shot by shot basis. To line up the UV DIAL pair, the software requires several inputs:

1. Determine and input the word number of the laser fire. This can most easily be done by transmitting the IR return and noting the word number of saturation (using the LIST -I,J command). Input the word number with the LASFIR I command.

2. Check the offset between the actual laser fire and the delayed trigger markers. This offset is currently 13 words or 1.3 usecs. Enter the number of words with the TODLY command.

3. With both the PMT returns and the trigger markers going into the digitizer make sure the trigger markers can still be discerned. If not, an adjustment of the light pipe may be neccessary. The trigger levels must be specified for single shots so if data is being averaged in the digitizer you must either divide the level by the number of shots averaged or do a TWEEK operation on the digitizer unit. The trigger level is entered as less than (<), greater than (>), or equal to (=) some value (eg. TRGLEV < 0, > 900, = -2048). Do not forget to return to normal data averaging when done using TWEEK 0.

The above three steps should be repeated for each digitizer unit with DIAL pairs. Data alignment of the single return aerosol data is not as critical but still important for comparisons with the DIAL data and accurate determination of aerosol layers. Actually, all data pairs (either DIAL or single aerosol returns) can be aligned using only one set of trigger markers since if there is any jitter between the on and offline laser timing it will be the same in each unit. Future plans are to include a trigger search during data transmission and to include these findings in the shot header.

The trigger search routine looks for the trigger marker in the 11 words centered around where it expects to find one as specified by the inputs LASFIR and TODLY. For example, LASFIR is set for 7, TODLY is 13, and TRGLEV is =2048 then the trigger search routine expects to find a value of 2048 between word 15 and word 25 of the online return and between WORDS1 + 15 and WORDS1 + 25 for the offline. If a value is found before that window or no value is found at all within the 11 words searched then the data shot is not included in the concentration calcula-tion. MODE 2 display does a trigger search on each return so inputs can be checked by displaying MODE 2. The valid trigger words are displayed in the lower righthand side of the screen as

they are found. Invalid markers are denoted by an asterisk.

One more word of caution. The occurrence of the trigger marker in the data stream can be altered by switch settings on the digitizers as well as by the command STORE. The Transiacs have a pre-trigger dial which increments by 512 words (for 4096 word record length). To allow for an ample window for the trigger marker the Transiac should be set at 1/8 (3584 words stored after the trigger and 512 words before). When the data from the digitizers is transferred into computer memory for storage to magnetic tape, the operator has the option of selecting where to begin storage with the instruction STORE. This command is especially useful with the Transiacs since so many pre-trigger words need be digitized. It also helps to conserve on storage when the first return in the digitizer is of no interest and only the second return need be saved (such as the zenith operation measurements). It has also been found that sometimes one of the amplifiers will cause a one word offset of the entire data set. When this happens, a STORE value should be input to the program to bring that data set in line with the other units.

Figure 12 shows digitizer memory as compared to computer memory for the keyboard commands as follows:

```
STORE   490,490,490,490
WORDS1  650,1350,600,600
WORDS2  650,1350,1400,1400
```

The events shown at the top of the figure are defined in the following table:

Event		Time (usec)	Word #
A	On-line laser fires	0	499
B	TOA light pipe marker	1.3	512
C	PMT A-gate turns on	5	549
D	Ground return (4500 M)	30	799
E	Time base "sleeps" for 163.7 usecs	136.2	1861
F	Off-line laser fires	300	1862
G	TOB light pipe marker	301.3	1875
H	PMT B-gate turns on	305	1912
I	Ground return (4500 M)	330	2162

The sample dialogue on the following page shows how to start the computer and run the DIAL DAS OS. This dialogue follows the typical sequence performed during actual flight experiments. Lines followed by comments preceded by two hyphens (--) are user inputs. Lines followed by comments in parentheses are computer responses. The use of some of the DIAL DAS OS commands are shown.

AB C   D   E FG H   I

4095   TOA MARKER   TOB MARKER

ON LINE UV ↓   OFF LINE UV ↓

GROUND   GROUND

DIGITIZER UNIT I UV ↓

0

MEMORY WORD 0   512 549   1875 1912   → 4096

4095

ON LINE UV ↑   OFF LINE UV ↑

DIGITIZER UNIT 2 UV ↑

0

0   549   1912   → 4096

4095

GROUND

IR ↓   IR ↑

DIGITIZER UNIT 3 IR

0

0   499   1862   → 4096

4095

VIS ↓   VIS ↑

GROUND

DIGITIZER UNIT 4 VIS

0

0   549   1912   → 4096

4095

DATA STORED IN CPU MEMORY

0

651   1301   2651   4001 4651   6051 6701   8100
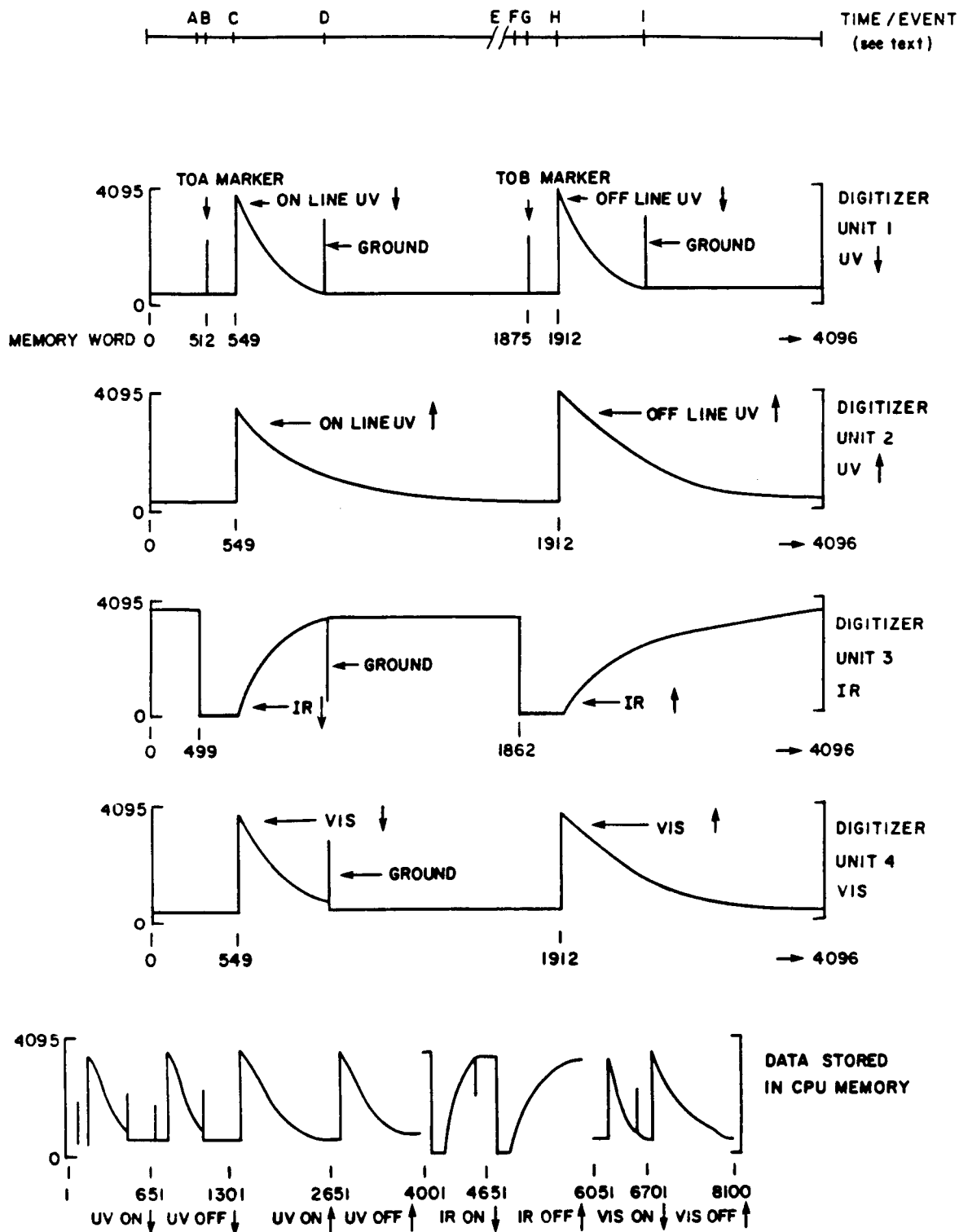
UV ON ↓ UV OFF ↓   UV ON ↑ UV OFF ↑   IR ON ↓   IR OFF ↑   VIS ON ↓ VIS OFF ↑

Figure 12.   Example of digitizer memory as compared to saved buffer memory.

Sample DIAL DAS dialogue. The dialogue sequence on the following pages
is typical of an actual flight experiment. The first two pages show the
procedure to align the different returns with each other, which is not
necessary to perform on each flight provided the returns are stable.
The third page shows the commands necessary to display the returns for
optimization, record to tape and perform color maps of aerosol and ozone.

```
.R TIME                          -- RUN PROGAM TO SET CRYSTAL CLOCK
MARK TIME BY TYPING LETTTER "P"
ENTER TIME HRS,MINS,SECS:  13,25,30  -- TYPE TIME IN HERE
022204                           (TIME PROGRAM HALTS AND WAITS FOR MARK)
@P                               -- TYPE "P" TO MARK THE TIME
STOP --                          (TIME IS LATCHED, TIME PROGRAM STOPS)
.RUN MASTER                      -- RUN PROGRAM "MASTER"
.RUN J11                         (LSI #1 TELLS LSI #2 TO RUN POGRAM "J11")
@R7/0010040  1000                (LSI #1 OPENS STACK POINTER REG ON JFEP AND LOADS IT WITH ADDRESS 1000)
@P                               (LSI#1 TELLS JFEP OUT TO RUN J11 WHICH HAS BEEN LOADED STARTING AT 1000)
.RUN SLAVE                       (LSI #1 TELLS LSI #2 TO RUN PROGRAM "SLAVE")
                                 (LSI #1 PRINTS OUT RESIDENT BANNER RECORD)
.... BANNER RECORD ...
TAPE =   1  FILE:   0  HEADER WORDS= 40  DATE=  6/5/87
ALT=     0  UP/DOWN=  0  SAMP FRE=  10  LASER FIRE=   9
REP RATE=  5  ABS COEF= 101E-20    WAKEUP=1362
UNIT WRDS1 WRDS2    START  BASE   TRIG  DELAY  SPECIES   DATAV6
  1   600   600      490     0  >  200    5      03         5
  2  1350  1350      490  4095  >  300    5      03         5
  3   600  1400      490  4095  =    0    5      IR         5
  4   600  1400      490     0  >  150    5      VIS        5
A/D CONVERSION CONSTANTS                    ENERGY CONVERSION
CHAN   SLOPE    OFFSET               CHAN    SLOPE       OFFSET
  1   4000.     -1000.                 1    0.73E-02     -3.23
  2     15.0      -75.                 2    0.42E-02     -1.12
  3     10.0      -10.                 3    0.125       -47.2
  4     20.       -50.                 4    0.1326       -7.44
  5      0.0       0.0                 5    0.55E-02     -1.68
?START                          --  START DATA TRANSFER FROM DIGITIZERS (SEE FIGURE 12 FOR DATA STORAGE)
?TWEEK 1                         --  TRANSFER UNIT 1 AT PULSE FREQUENCY
?LIST -1,30                      --  LIST LAST BUFFER FROM WORDS 1 TO 30
SHOT =   151   AVG = 1
            0    1    2    3    4    5    6    7    8    9

    1      300  302  299  305  301  303  299  300  500  301
   11      300  303  305  302  300  301  299  301  300  300
   21     1631 1684 1691 1723  300  300  304  300  302  303
?LIST -601,630                  --  LIST OUT FIRST 30 WORDS OF OFFLINE RETURN
SHOT =   186   AVG = 1
            0    1    2    3    4    5    6    7    8    9

  601      310  304  301  308  307  299  304  300  302  473
  611      300  301  301  307  298  301  306  302  303  309
  621      303 1530 1555 1493 1256  376  302  303  305  301
?LASFIR 9                       --  LASER FIRE IS AT WORD 9 OF ONLINE DATA
?TODLY 14                       --  TRIGGER MARKER FOR UNIT 1 IS DELAYED 14 WORDS
?TRGLEV >400                    --  CHANGE TRIGGER LEVEL OF UNIT1 TO >400
?TWEEK 0                        --  RETURN UNIT 1 TO 5 SHOT ACCUMULATIONS
?STOP                           --  STOP DATA TRANSFER
?WAKEUP 1363                    --  ALIGN OFFLINE TO ONLINE DATA
?START                          --  START DATA TRANSFER
?TWEEK 1                         --  SINGLE SHOTS ON UNIT 1
?LIST -601,630                  --  LIST OUT FIRST 30 WORDS OF OFFLINE RETURN
SHOT =   229   AVG = 1
            0    1    2    3    4    5    6    7    8    9

  601      304  301  308  307  299  304  300  302  473  310
  611      300  301  301  307  298  301  306  302  303  309
  621     1563 1530 1555 1493  362  306  302  303  305  301
?TWEEK 2                        --  RETURN UNIT 1 TO 5 SHOTS, TAKE SINGLE SHOTS ON UNIT 2
?LIST -1201,1230                --  LIST UNIT 2/ONLINE FIRST 30 WORDS
SHOT =   251   AVG = 1
            0    1    2    3    4    5    6    7    8    9

 1201     3900 3902 3909 3905 3901 3903 3909 3900  500 3901
 1211     3900 3903 3905 3902 3900 3901 3909 3901 3900 3900
 1221     1631 1684 1691 1723 3900 3900 3904 3900 3902 3903
?LIST -1551,1580                --  LIST UNIT 2/OFFLINE FIST 30 WORDS
```

```
SHOT =    372 AVG = 1
            0    1    2    3    4    5    6    7    8    9

1551       3904 3901 3900 3907 3909 3904 3900 3902 1296 3909
1561       3900 3901 3901 3907 3900 3901 3906 3902 3903 3909
1571       1530 1555 1493 1256 3976 3902 3903 3905 3901 3900
?TOOLY ,14              -- TRIGGER MARKERS ON UNIT 2 ARE DELAYED 14 WORDS
?TRGLEV ,3800          -- LOOK FOR LEVEL LESS THAN 3800
?TWEEK 3               -- RETURN UNIT 2 TO 5 SHOTS, TAKE SINGLE SHOTS UNIT 3
?LIST -3901,3930       -- LIST UNIT 3/ONLINE FIRST 30 WORDS
SHOT =    462 AVG = 1
            0    1    2    3    4    5    6    7    8    9

3901       3900 3902 3909 3905 3901 3903 3909 3900    0    0        \
3911          0    0    0    0    0    0    0    0    0    0
3921          0    0    0    0    0    0    0    0    0    0
?LIST -4501,4530       -- LIST UNIT 3/OFFLINE FIST 30 WORDS
SHOT =    572 AVG = 1
            0    1    2    3    4    5    6    7    8    9

4501       3904 3901 3900 3907 3909 3904 3900 3902    0    0
4511          0    0    0    0    0    0    0    0    0    0
4521          0    0    0    0    0    0    0    0    0    0
?TOOLY ,,0             -- WILL USE ACTUAL LASER FIRING AS MARKER (NO DELAY)
?TRGLEV ,,=0           -- WILL LOOK FOR SATURATION ON UNIT 3
           (AT THIS POINT THE TRIGGERS ON UNIT 4 SHOULD BE CHECKED. SINCE WE HAVE ONLY 2 LIGHT PIPE OUTPUTS WHICH HAVE
           ALREADY BEEN USED ON UNITS 1 AND 2, AND NOT SUFFICIENT POCKEL CELL NOISE ON THE VISIBLE TUBE TO USE AS A MARKER,
           WE MIGHT TEMPORARILY USE THE MARKERS OF UNIT 1 TO CHECK THE DATA)
?TWEEK 4               -- RETURN UNIT 3 TO 5 SHOTS, TAKE SINGLE SHOTS ON UNIT 4
?LIST -5901,5930       -- LIST UNIT 4/ONLINE FIRST 30 WORDS
SHOT =    505 AVG = 1
            0    1    2    3    4    5    6    7    8    9

5901        500  502  509  505  501  503  509  500  500  501
5911        500  503  505  502  500  501  509  501  502 1622
5921       1601 1600 1591  523  500  500  504  500  502  503
?LIST -6501,6530       -- LIST UNIT 4/OFFLINE FIST 30 WORDS
SHOT =    525 AVG = 1
            0    1    2    3    4    5    6    7    8    9

6501        504  501  508  507  509  504  500  502  508  509
6511        500  501  501  507  500  501  506  502  503 1609
6521       1530 1555 1493  526  506  502  503  505  501  500
?TWEEK 0               -- RETURN UNIT 4 TO 5 SHOTS
?TOOLY ,,,14           -- MARKER IS DELAYED 14 WORDS
?TRGLEV ,,,>600        -- MARKER MUST BE GREATER THAN 600
?STOP                  -- STOP DATA TRANSFER
?STORE ,,,409          -- UNIT 4 IS TRIGGERING 1 WORD EARLY SO BY STORING 1 WORD SOONER WE CAN LINE IT UP WITH OTHER UNITS
?START                 -- RESTART DATA TRANSFER
?HEIGHT 15000          -- PLACE AIRCRAFT ALT IN BANNER
?LSTBNR                -- LIST OUT NEW BANNER RECORD
... BANNER RECORD ...
TAPE =      1  FILE=    0  HEADER WORDS= 40  DATE=  6/5/87
ALT=    15000  UP/DOWN= 0  SAMP FRE=  10  LASER FIRE=   9
REP RATE=   5  ABS COEF= 101E-20  WAKEUP=1363
UNIT  WRDS1  WRDS2     START   BASE   TRIG   DELAY  SPECIES  DATAWG
  1     600    600       490      0  > 400      5      03       5
  2    1350   1350       490   4095  < 3800     5      03       5
  3     600   1400       490   4095  =    0     5      IR       5
  4     600   1400       409      0  > 600      5      VIS      5
A/D CONVERSION CONSTANTS                ENERGY CONVERSIONS
CHAN   SLOPE     OFFSET          CHAN    SLOPE      OFFSET
  1    4000.     -1000.             1   0.73E-02    -3.23
  2      15.0      -75.             2   0.42E-02    -1.12
  3      10.0      -10.             3   0.125       -47.2
  4      20.       -50.             4   0.1326       -7.44
  5       0.0        0.0            5   0.55E-02     -1.68
?UNIT 1                -- DISPLAY NADIR UV BY ITSELF
```

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```
?ONLINE                    -- DISPLAY ONLINE UV FOR OPTIMIZATION
?OFFLINE                   -- DISPLAY OFFLINE UV FOR OPTIMIZATION
?BOTH                      -- DISPLAY BOTH UV'S FOR PMT OPTIMIZATION
?UNIT 2                    -- DISPLAY ZENITH UV
?ONLINE                    -- DISPLAY ZENITH UV ONLINE FOR OPTIMIZATION
?OFFLINE                   -- DISPLAY ZENITH UV OFFLINE FOR OPTIMIZATION
?BOTH                      -- SET PMT TO BRING BOTH ON SCALE
?UNIT 3                    -- DISPLAY IR
?ONLINE                    -- DISPLAY NADIR I FOR OPTIMIZATION
?OFFLINE                   -- DISPLAY ZENITH IR FOR OPTIMIZATION
?BOTH                      -- SET AMPLIFIER GAINS FOR BOTH
?UNIT 4                    -- DISPLAY VISIBLE
?ONLINE                    -- DISPLAY NADIR VIS FOR OPTIMIZATION
?OFFLINE                   -- DISPLAY ZENITH VIS FOR OPTIMIZATION
?BOTH                      -- SET PMT GAINS FOR BOTH
?STACK                     -- WILL GATHER VIS AT 5 HZ
?RECORD                    -- EVERYTHING IS READY, SO RECORD
?UNIT 3                    -- DISPLAY IR
?ONLINE                    -- NADIR IR ONLY
?RNGCOR 1                  -- RANGE SQUARE DATA
?@BLACK 1500               -- DETERMINE SCALING FOR AEROSOL COLOR MAP
?MAPAER                    -- START AEROSOL COLOR MAP
?OZONE                     -- DO OZONE CALCULATION
?%BLACK 750                -- DETERMINE SCALING FOR OZONE COLOR MAP
?MAPUV                     -- START OZONE COLOR MAP
?ENDFIL                    -- DONE WITH LEG, END THE FILE
?AEROFF                    -- END AEROSOL COLOR MAP
?UVOFF                     -- END OZONE COLOR MAP
?STOP                      -- STOP DATA TRANSFER
?LOLEG                     -- CALL UP PARAMETERS FOR A LOW LEG
?START                     -- START DATA TRANSFER
?HEIGHT 500                -- ENTER NEW PLANE ALTITUDE
?LSTBNR                    -- LOOK AT LOW LEG BANNER DEFAULTS
  ... BANNER RECORD ...
TAPE =     1  FILE=    1   HEADER WORDS= 40   DATE= 6/5/87
ALT=     500  UP/DOWN= 1   SAMP FRE=  10   LASER FIRE=   9
REP RATE=   5   ABS COEF= 101E-20   WAKEUP=1363
UNIT  WRDS1  WRDS2   START  BASE   TRIG   DELAY  SPECIES  DATAVG
  2    1350   1350     490  4095  < 3800     5      O3       5
  3       0   1400    1053  4095  =    0     5      IR       5
  4       0   1400    1053     0  >  500     5      VIS      5
A/D CONVERSION CONSTANTS                ENERGY CONVERSIONS
CHAN   SLOPE    OFFSET               CHAN   SLOPE    OFFSET
  1   4000.    -1000.                  1   0.73E-02  -3.23
  2     15.0     -75.                  2   0.42E-02  -1.12
  3     10.0     -10.                  3   0.125    -47.2
  4     20.      -50.                  4   0.1326    -7.44
  5      0.0       0.0                 5   0.55E-02  -1.68
?UNIT 2                    -- SET AMPLIFIER AND PMT GAINS FOR UV
?UNIT 3                    -- SET AMPLIFIER GAIN FOR IR
?UNIT 4                    -- SET AMPLIFIER AND PMT GAINS FOR ZENITH VIS
?RECORD                    -- RECORD DATA (NO STACKING ON LOW LEG)
?UNIT 3                    -- DISPLAY ZENITH IR
?RNGCOR 1                  -- RANGE CORRECT
?@BLACK 2000               -- DETERMINE SCALING FOR AEROSOL COLOR MAP
?MAPAER                    -- START AEROSOL COLOR MAP
?MAPUV                     -- START OZONE COLOR MAP
?ENDFIL                    -- END OF LEG, END THE FILE
?AEROFF                    -- STOP AEROSOL COLOR MAP
?UVOFF                     -- STOP OZONE COLOR MAP
?HILEG                     -- SET UP FOR HIGH LEG
     (AND SO ON.................)
```

KEYBOARD COMMANDS

After the start-up procedure outlined above, all further keyboard input is interpreted by the program MASTER. A complete set of legal commands are listed on the following pages. A single character of operator input can be erased by means of the BACKSPACE (←) key. An entire line can be erased using the DEL key. The DIAL DAS OS is brought on-line with predefined option defaults. Data transfer from the digitizers can be initiated immediately if these defaults are suitable by means of the START command. Once START has been entered the program is interrupt-driven by the digitizers and certain parameters should not be changed. Commands that change these parameters are listed in the section "Stop Mode Commands" and can be used only after STOP has been entered. Also included in the "Stop Mode Commands" are those commands which deal with the interaction of the two LSI's. These commands can only be issued in stop mode to prevent the computers from getting out of sync. Error messages are detailed in Appendix III.

In the following list of commands, the variables U1, U2, U3, and U4 are used to refer to input parameters for digitizer units #1, #2, #3, and #4 respectively. The Transiacs can be used in any order which is determined by the command CAMACS whose input parameters list the station numbers of each unit in the sequence in which they are to be read. Once the order has been established by the CAMACS command all other commands that have unit numbers as variables will follow that order.

Commands which have been changed or added since last year's report are denoted by a plus symbol.

Stop Mode Commands

1. Digitizer Storage Commands:

+	WORDS1 U1,U2,U3,U4	# points/return #1 for each unit
+	WORDS2 U1,U2,U3,U4	# points/return #2 for each unit
	STORE U1,U2,U3,U4	store from this word for each unit
	CAMACS I,J,K,L	station # for Transiacs to be used
+	DATAVG U1,U2,U3,U4	# shots to sum before storage
	LOLEG	calls for a number of defaults used during low altitude passes
	HILEG	calls up a number of defaults used during high altitude passes
+	WAKEUP I	word separation in digitizer between first and second returns

2. Play-Back Commands:

    PLOT   I   plot I shots from tape
                                     if I=-1 plot from memory

3. LSI #2 Program Control Commands:

    BOOT   boot LSI #2 then run program SLAVE
    SLAVE   run program SLAVE on LSI #2

Start or Stop Mode Commands

1. Program Control Commands:

START		start data transfer from digitizers
STOP		stop data transfer
RESTRT		clears interrupts and issues a macro RESET command which returns all units to their status at power-up time
SYNC		synchronize the two computers --used when monitor display fails to update
KILL		kill program MASTER and return to Monitor
+ STACK		record in stacked format the last unit at 5 Hz rep rate
SHTSET		reset shot counter to zero
LSTBNR		print out current banner record
LSTPLT		print out current plotting options
COPY	I	copy CRT to Trilog (sizes: I=1-4)
PRINT		plot buffer is printed out on Trilog
LIST	I,J	print data buffer from word I to J if I<0 print buffer in memory if I>0 read buffer from tape

2. Banner Record Input:

FORMAT	I	format # (=2 presently)
TAPE	I	tape #
FILE	I	file #
HDRPTS	I	reserve I words in shot header
UPDOWN	I	I=0 down-looking; I=1 up-looking
PULFRE	I	pulse repetition frequency (Hz)
SAMFRE	I	sampling rate (MHz)
+ HEIGHT	I	plane altitude (ft)--for altitudes greater than 32000 use $-I/10$
PRETRG	I	# words stored before trigger marker
ABSCOF	I,J	absorption coefficient $I*10**J$ $(atm-cm)-1$
TODLY	U1,U2,U3,U4	# words offset between marker and actual laser firing
DELAY	U1,U2,U3,U4	usecs after trigger to start of return
GASES	U1,U2,U3,U4	3-letter gas identifier (AER,O3,H2O)
BASLIN	U1,U2,U3,U4	base line for returns
TRGLEV	aU1,bU2,cU3,dU4	trigger marker level where a,b,c,d can be = or < or >

3a.   Calibration Constants For Met Data:

ADCH1   I,J,K,L   altitude   slope (I*10**J) and intercept (K*10**L)
ADCH2   "   altitude-radar   "
ADCH3   "   dewpoint   "
ADCH4   "   PRT temp   "
ADCH5   "   total temp   "
ADCH6   "   Gregory ozone   "

3b.   Conversion Constants For Laser Energy Data:

EMCH1   I,J,K,L   channel 1   slope (I*10**J) and intercept (K*10**L)
EMCH2   "   channel 2   "
EMCH3   "   channel 3   "
EMCH4   "   channel 4   "
EMCH5   "   channel 5   "
EMCH6   "   channel 6   "

4.   Magnetic Tape Commands:

CIPHER   I   cipher unit # (I=1 or 2)
RECORD   write banner and start recording
BANNER   write banner
ENDFIL   write EOF and stop recording
REWIND   rewind tape to BOT
SKPEOI   skip to 2 consecutive EOF's
FNDFIL   I   search for file I (forward only)
SKPFIL   I   skip forward I files
BAKFIL   I   skip backward I files
SKPREC   I   skip forward I records
BAKREC   I   skip backward I records

5.   Plotting Options Commands:

TWEEK   I   sample and display unit I at rep rate
FLTMOD   I   select plot mode I (I=0 for no display)
MODE 1   raw data display
MODE 2   on/off line overlay display
OZONE   ozone concentration display mode
WATER   water vapor concentration display mode
FLTGRY   I   plot gray scale if I=1
GRYSCL   CRT aerosol gray scale display
UNIT I   display unit I data only
ONLINE   show on-line return only
OFFLINE   show off-line return only
BOTH   show both on-line and off-line
RETURN   U1,U2,U3,U4   plot return # for each unit (both=7)
SCALE   I   plot scale factor where scale=2**I
YMAX   I   display range interval (see note #2)
BLOWUP   subtract background and blowup to scale=0
OFFSET   I   offset x-axis by I
CLEAR   I   clear CRT (0=no clear;1=data only;15=all)
OVRLAY   I   overlay data from different units if I=1
BGWORD   I   start word # for background average

```
       BGWIND   I                        # words to average for background (window)
       SUBBAK   I                        subtract background if I=1
       RNGCOR   I                        range correct if I=1
       SMOOTH   I                        smooth data over I meters (max 105m)
       FLTAVG   I                        average I shots in display
       INDEX    I                        index of I through data buffer (if I=0
                                         program computes index necessary to fit
                                         data on screen)
       FIXPNT   I                        I pixels plotted per data point
       UPDATE   I                        I = 0 update plot and right screen
                                         I = 1 update plot only
                                         I = 2 update right screen only
       RNGCEL   I                        use range cell of I meters
       GASEXP   I                        concentrations in parts *10**I
       SHFTOA   I                        shift TOA marker by I words
       ATMCOR   I                        if I=1 correct concentrations for
                                         altitude change of standard atmosphere
                                         (this correction not necessary when
                                         the absorption cross-section is changing
                                         with altitude as well)
       RAYCOR   I                        Rayleigh correction in same units as
                                         GASEXP above
```

6.   Aerosol Color-Scale Commands:

```
+      MAPAER                            start real-time color map of aerosol
+      AEROFF                            stop real-time color of aerosol
       @EXPAND   I                       zoom factor (default is 3)
       @WHITE    I                       minimum value of range corrected signal
                                         -- when it falls below this value it
                                         will be white
       @BLACK    I                       maximum value of range corrected signal
                                         -- when it falls above this value it
                                         will be black
       @ALTCOR   I                       aligns data such  that  pressure
                                         altitude ground is at third tic mark from
                                         bottom
       NORMAL    I                       normalizes return by EO/E where  EO
                                         is  first  shot energy computed for energy
                                         monitor channel I and E  is the energy of
                                         that channel on each shot
       @CUTOFF   I                       zero fill data if value greater than I
       @MARKER                           places a solid black line on plot
       @RETURN   I                       plot the I return (either 1 or 2)
       @LABEL    I                       place time and postion every I minutes
```

     The following commands are identical in function as those
listed in the previous section but the "@" preceding each command
directs the action to the color aerosol display on the Act II.

```
       @UNIT       @SMOOTH    @BGWORD     @BGWIND     @INDEX      @FLTAVG
```

7. Ozone Color-Scale Commands:

```
+    MAPUV                    start real-time color map of ozone
+    UVOFF                    stop real-time color of ozone
+    *WHITE     I             minimum value of ozone
                              -- when it falls below this value it
                              will be white
+    *BLACK     I             maximum value of ozone
                              -- when it falls above this value it
                              will be black
+    *ALTCOR    I             aligns data such  that  pressure
                              altitude ground is at third tic mark from
                              bottom -- only works for nadir data
+    *LABEL     I             place time and postion every I minutes
```

The following commands are identical in function as those
listed in the previous section but the "*" preceding each command
directs the action to the color ozone display on the Act II.

```
*UNIT      *BGWORD    *BGWIND    *SMOOTH    *RNGCEL    *PLTAVG
*INDEX     *GASEXP    *SHFTOA    *ATMCOR    *RAYCOR
```

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